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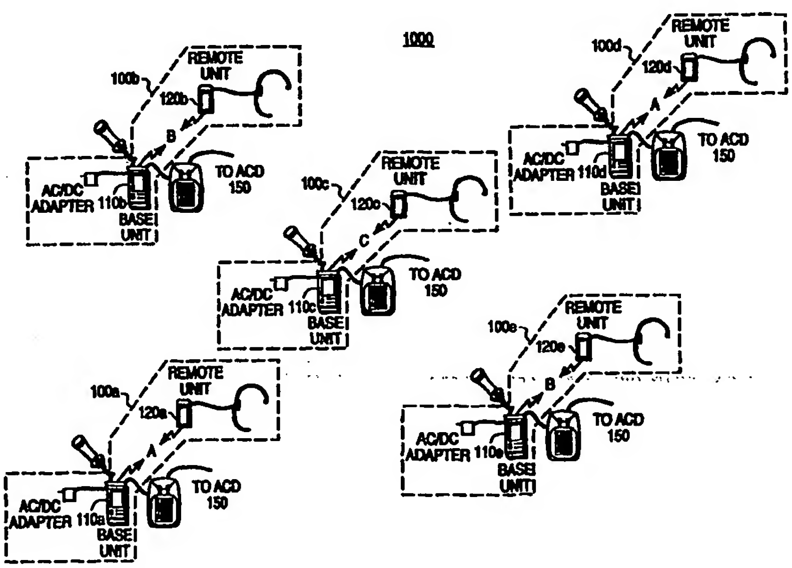
(54) Title: SHORT RANGE MAGNETIC INDUCTIVE COMMUNICATION

(57) Abstract



Audio communication using magnetic inductive (MI) fields for a full duplex cordless communication link is disclosed. A single communication system can include a base unit and a remote unit with a headset which are linked cordlessly by MI signals. The base unit receives audio signals from a host system, frequency modulates a carrier frequency signal, and transmits this to the remote unit as an MI signal. The remote unit receives the MI signal and demodulates it to produce the base audio signal which is passed to the headset. Similarly, the remote unit receives audio signals from the headset (typically the user's voice), frequency modulates a carrier frequency signal, and transmits this to the base unit as an MI signal, whereupon the base unit receives and demodulates the MI signal to produce the remote audio signal for passage to the host system. Frequency modulation allows for a plurality of cordless communication channels across a usable spectrum of frequencies. The provision of a plurality of channels and full duplex MI links allows implementation in high user density applications, wherein a plurality of cordless communication channels are used to allow independent cordless links between unit pairs. Channel allocation including channel slots with a bandwidth that exceeds the occupied bandwidth for signals transmitted between the units facilitates the avoidance of interfering signals without requiring channel slot redefinition. Security codes are provided to prevent unpaired units from communicating with each other. A supervisory remote unit is able to receive signals from any base unit without verification of the security code. Under various circumstances, an agent not available signal is transmitted to a telephone system to indicate the availability or unavailability of a telephone line.

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SHORT RANGE MAGNETIC INDUCTIVE COMMUNICATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to communication systems, more particularly to cordless audio communication systems, and still more particularly to audio communication systems that implement magnetic inductive signals to establish a full duplex cordless link.

2. Description of the Related Art

Audio headsets have been used in the work place and home for various purposes including telecommunications. Various advantages and factors can be attributed to the apparent increase in the use of audio headsets. One advantage is that audio headsets enable the user's hands to remain free during operation, which allows operation of keyboards and other equipment, even while the headset is in use. Additionally, audio headsets are practical for applications where several users are present in a common area, such as a telephone call centers including reservation service centers, customer service centers, and the like. There are several reasons for this. Since the headset earphones are mounted in or near the ear and the headset microphone is located near the mouth, its use is less likely to radiate sound into the ambient environment than is the use of conventional loudspeaker type communication systems. This reduces the distraction that one user may cause to another working nearby. Additionally, again because of the headset earphones are mounted in or near the user's ears, it is easy for the user to hear communications through the headset even where a lot of ambient acoustic audio is present.

Many conventional audio headsets include wires or cords that are used to transmit signals between the headset and a host system. While these headsets offer some of the advantages noted above, they are problematic for various reasons. For example, the cord inhibits user freedom by tethering the user to the host system. Additionally, the cord can interfere with the operation of other equipment and can

become tangled. Thus, for many applications, cordless headsets are preferable to corded ones.

Although cordless headsets are sometimes preferable, they present problems that may not be present with corded headset. One problem is the possibility of signal interference in the frequency spectrum that is used for cordless signal transmission. Interference can result from various sources including background noise in the frequency spectrum, local emissions from devices such as video monitors or lights, and, where applicable, the audio signals transmitted by similar communication systems in the local area. Another problem is the possibility of unintentional signal interception, such as conversation "eaves-dropping" by parties with similar headsets. Further, because cordless headsets rely on some type of frequency allocation scheme within a limited bandwidth, unintentional interception may occur where there are hundreds, or perhaps thousands of users. The various interception problems are particularly of concern in environments such as call centers where many users are present.

There are cordless headset and communication system design concerns in addition to the avoidance of interference and interception. For example, full duplex operation is a desirable feature. Full duplex refers to the ability to transmit and receive simultaneously, and is very useful for real time two way conversations. Moreover, conventional telephone handsets provide full duplex operation, and cordless headset users expect similar performance.

Another concern in cordless headset design is the need for supervisory equipment. For example, although the security of cordless communication is sought to prevent signal interception, in some applications certain parties, such as user group supervisors, may want to listen to the conversation of a particular user of a cordless headset. Specifically, in certain high user density applications, a supervisor may want to listen to portions of conversations by various users. In a cordless environment, it would be desirable for the supervisor to be able to freely wander through the facility

and selectively listen to such conversations. Thus, while the user's communications should generally be secure, they should also permit access by selected parties.

Yet another design concern is the possibility of government regulation of the signals used for cordless signal transmission. For example, in the United States, the Federal Communications Commission (FCC) regulates certain radio frequency (RF) communications. Finally, power consumption is a concern, since the portable portion of the cordless headset is reliant upon a local power source, such as a battery with a finite capacity having a weight that is typically proportional to the capacity. It is desirable to provide sufficient battery power in a cordless headset for long duty cycles, yet large capacity batteries make a headset bulky and uncomfortable for long periods of use.

Thus, there remains a need for improvements in the design of cordless communication systems, most particularly those implementing cordless audio headsets where high quality full duplex communication is sought in high user density applications. Additionally, among other things, designs which provide high quality full duplex communication while minimizing the likelihood of interference, which prevent interception while allowing access by appropriate parties, which minimize power consumption and portable unit weight, and which facilitate implementation in high user density applications are sought.

SUMMARY OF THE INVENTION

The present invention provides for cordless audio communication in a system including a base unit and a portable remote unit with a headset. Magnetic Inductive (MI) fields provide a cordless link between the base unit and the remote unit. Since MI fields have a field strength which diminishes rapidly with range, signal interference from the operation of similar units in close proximity is minimized. This allows better implementation in multiple system user environments, and particularly in high user density applications. A channel allocation scheme provides a plurality of independent full duplex cordless communication channels and allows the avoidance of interfering signals. This also allows the cordless communication system to be implemented in multiple user environments.

The channel allocation scheme subdivides the signal spectrum available for cordless communication, and thus allows the establishment of multiple, independent communications links. This allows an increase in the number of cordless systems that can be used in a limited area (i.e. it allows cordless systems to be used in high user density applications). An additional feature of the channel allocation scheme is that signals transmitted from the base unit to the remote unit correspond to a first channel and the signals transmitted from the remote unit to the base unit correspond to a second channel. This facilitates full duplex signal transmission between the units. In another aspect, the first and second channels are related by a fixed frequency difference. This further facilitates full duplex operation, and, moreover, allows signal modulation with relatively less complex circuitry.

In another aspect beneficial to high user density environments, the channel allocation scheme allows channel relocation and, thus, the avoidance of interfering signals, without requiring adjacent or related channels to be redefined. That is, the channel allocated to one user may be dynamically reallocated without effecting the channels in use by others. In one aspect, this is provided by defining a series of channel slots having a bandwidth that exceeds the bandwidth used to actually

transmit signals. This allows relocation of the occupied portion of the channel slot, without encroaching upon the boundaries of other channels. Thus, to avoid interference at a particular frequency within the channel slot, the occupied bandwidth can be redefined to avoid the particular frequency, but still reside within the allocated channel slot to allow coherent communication and avoid interference with other units operating at adjacent channels.

Security features are also provided to avoid signal interference and interception. Particularly, in high user density applications, an unintended user may inadvertently enter into the operating zone of a user whose system is operating on the same channel. This situation could allow talk-over (the unintended user's voice is transmitted over the proper user's channel) or eavesdropping (the unintended user hears the proper user's conversation). To prevent these types of breaches in the security of a channel(s) allocated to a particular system, a security code is provided. For example, the security code can be verified between the base unit and remote unit when necessary to confirm the propriety of communication between the units in a system, to allow continued and uninterrupted communication between the units where the security code has been confirmed, and to prevent intrusion by other units. A link closure and recovery protocol is provided in conjunction with the security code to allow proper users to drift in and out of the zone of operation without being immediately or permanently cut off, and to prevent intrusion by unintended users who drift into the operating zones of other systems.

The power used to transmit signals between units is tailored to allow high quality communication while minimizing interference with the operation of other units and power consumption, particularly at the remote unit. Specifically, the separation, or the distance between a remote unit and its associated base unit is monitored, and the amount of power used to transmit signals, particularly from the remote unit to the base unit, is adjusted according to the distance. In addition to separation monitoring, a detection of ambient conditions (e.g. the amount of background noise, the proximity of

interfering sources), and the quality of signal transmission particular to the system may be monitored to dynamically adjust the transmit power.

Sometimes a second party may need to listen to the conversations of a user or users. For example, in certain multiple user applications such as call centers, a supervisor may monitor calls for training, evaluation or quality control. A remote unit with a supervisory mode is provided to monitor the communications of a plurality of the user remote and base units. The supervisory remote unit is arranged to receive signals transmitted from various base units without requiring a security code, and to operate according to the channel allocation of the base unit in the operating zone in which the supervisory unit currently resides. Thus, a supervisor may walk about an area including a plurality of users and monitor the communications of such users. Because of the proximity of the supervisor remote unit to the user base unit being monitored, the supervisor should be able to hear the user's voice directly, so only the signals transmitted from that base unit to the user's remote unit need to be monitored. A targeted user is one that the supervisor would like to monitor. Specifically, as the supervisor moves about the area, the supervisor can hear the targeted user's voice directly (i.e., acoustically, through the air) and pick up the caller's voice from the MI signals transmitted to the user's remote unit. Alternatively, the supervisory remote unit could be arranged to transmit in "talk over" fashion.

In still another aspect beneficial to operation in multiple user environments the cordless link between base and remote units is used in conjunction with the agent availability function of a telephone system such as an automatic call distribution system. In one embodiment, the availability status of the telephone line is determined by examining whether the remote unit resides outside of its appropriate operating range for a predetermined period of time. Thus, if the remote unit leaves the operating range for an extended period, an agent-unavailable signal is generated and transmitted to the automatic call distribution system so that no further calls are directed to the remote unit that is not in range. The cordless link between the remote unit and the base unit can also be used to transmit an agent-unavailable signal from the remote unit

to the base unit. Specifically a user that is away from the base unit can use a switch or other actuating mechanism to cause an agent-unavailable signal to be transmitted to the base unit, which in turn can transmit the signal to the automatic call distribution center. An override switch can also be provided to selectively enable or disable the agent not available signal generation system of the RU. This allows a user to leave the operating range but still allows calls to be held for them by the automatic call distribution center.

Thus, the present invention provides high quality cordless communication appropriate for use with high user density applications. An exemplary embodiment of the present invention includes a base unit and a portable remote unit with a headset, and includes full duplex magnetic inductive field based signal transmission. Various additional features are provided, including channel allocation for efficient use of the available frequency spectrum, power conservation, signal security, and communication supervision.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other more detailed and specific features of the present invention are more fully disclosed in the following specification, in which:

FIG. 1A is a schematic illustrating an embodiment of a cordless audio communication system in accordance with the present invention.

FIG. 1B is a schematic illustrating an exemplary high user density application including a plurality of cordless audio communication systems in accordance with the present invention.

FIG. 1C is a schematic illustrating an automatic call distribution center with an embodiment of an agent not available module.

FIG. 2 is a block diagram illustrating an embodiment of a remote unit in accordance with the present invention.

FIG. 3 is a block diagram illustrating an embodiment of a base unit in accordance with the present invention.

FIG. 4A is a graphical diagram illustrating an embodiment of interfering tone avoidance in accordance with the present invention.

FIG. 4B is a graphical diagram illustrating an embodiment of channel allocation in accordance with the present invention.

FIG. 4C is a graphical diagram illustrating an embodiment of incremental operating frequency relocation in accordance with the present invention.

FIG. 4D is a graphical diagram illustrating an embodiment of full duplex channel slot allocation in accordance with the present invention.

FIG. 5A is a graphical diagram illustrating exemplary regulated frequencies.

FIG. 5B is a graphical diagram illustrating exemplary base unit to remote unit channel allocation in accordance with the present invention.

FIG. 5C is a graphical diagram illustrating exemplary remote unit to base unit channel allocation in accordance with the present invention.

FIG. 6 is a schematic illustrating an embodiment of security code verification in accordance with the present invention.

FIG. 7 is a schematic illustrating an embodiment of range determination in accordance with the present invention.

FIG. 8 is a schematic illustrating an embodiment of range based transmit power in accordance with the present invention.

FIG. 9 is a schematic illustrating an embodiment of aerial circuitry in accordance with the present invention.

FIG. 10 is an illustration of interference and operating frequency signals.

FIGs. 11A and 11B are a graphical and schematic illustration of an embodiment of determining the operating range and spacing for units in a high user density environment.

FIG. 12 is a schematic illustrating an embodiment of base unit firmware in accordance with the present invention.

FIG. 13 is a schematic illustrating an embodiment of remote unit firmware in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the schematic of FIG. 1, one embodiment of a cordless audio communication system 100 in accordance with the present invention is shown. The system 100 includes a base unit 110 (BU 110) with a power adapter 150, and a remote unit 120 (RU 120) with a headset 160. The BU 110 is coupled to a host system 130 which transmits and receives audio signals. The headset 160 includes one or more earphones and a microphone for the receipt and transmission of audio signals. Typically, the user speaks into the headset 160 microphone which converts the acoustic audio signal into an analog electrical signal that is provided to the RU 120 through a wired connection. Preferably, a cordless link between the BU 110 and RU 120 is established using magnetic inductive (MI) signals. The RU 120 transmits an MI signal for receipt by the BU 110 which reproduces the analog electrical signal and provides it

to the host system 130. In the other direction (BU to RU), the BU 110 receives an audio signal, usually an analog electrical signal, from the host system 130 and transmits an MI signal corresponding to the audio signal for receipt by the RU 120. MI signals are simultaneously transmitted and received by the units 110, 120 to provide full duplex, or real time two way communication between the user and the host system 130. Sometimes, the communication is between the user and a party on the other end of the host system 130, referred to as the caller where the host system 130 is a telephone system.

The power adapter 150 is arranged to convert conventional line AC power into DC power for use by the BU 110. Thus, the adapter 150 provides a relatively constant source of power that is used by the BU 110 to transmit and receive MI signals. The RU 120 includes a battery (not shown) that provides the power used for its production and transmission of signals. Additionally, the RU 120 interfaces with the BU 110 so that the power from the adapter 150 can be used to charge the RU 120 battery.

The host system 130 described in connection with this embodiment is a conventional public telephone system that implements a hardwired switching network and conventional telephone units having conventional handsets 140. When the RU 120 is not in use (e.g. while it is being charged), the handset 140 can be used for communication over the host system 130. Although a public telephone system is disclosed, it is understood that the host system 130 may also be a cellular communication system, a computer system, or any communication system. Additionally, although in this embodiment voice audio signals are communicated, other signals such as coded signals in the audio spectrum or digital data may be transmitted using the cordless MI link.

MI signals have a rate of decay that approximates to a cube law with distance, which is substantially higher than the rate of decay for other signals such as radio frequency signals. Thus, the same channel may be used by first and second systems 100 in a high user density application, even if the first and second systems 100 are adjacent to each other, provided that their separation distance is adequate. For

example, with an operating range of about 2 meters, the channel frequency could be reused after about 8-9 meters and still provide high quality (of course, the separation distance will vary dependent upon the user's signal quality desires and the particular details of the modulation scheme). Additionally, in the preferred embodiment the MI signals are frequency modulated (FM), and frequencies between 2 and 30 MHz (most preferably, 2-10 MHz) are used to transmit the signals between the units 110, 120. The use of MI in conjunction with FM signal transmission over these frequency ranges allows for the use of multiple cordless communication channels, which increases the number of systems that can operate in confined areas and thus facilitates high user density applications. This is because adjacent systems 100 operating on different frequencies will not interfere with each other. By contrast, with other signal transmission techniques, such as certain pulse position modulation (PPM) or pulse width modulation (PWM) techniques, the position or width of pulses in relation to time are used to convey information. With these transmission techniques, the signals for multiple systems are not inherently distinguishable from each other, as is possible with frequency modulation and the implementation of multiple channels in the present invention. Because of this, the number of units using the present invention's combination of frequency modulation and multiple channels in a confined area is significantly greater than would could be used with conventional PPM or PWM.

Referring now to the schematic of FIG. 1B, an exemplary high user density environment includes five cordless audio communication systems 100a, 100b, 100c, 100d and 100e. Each of the systems includes a cordless communication link between its base 110 and remote 120 units. Specifically, in system 100a, a communication link using channel "A" is used to transmit signals between the BU 110a and RU 120a, while in system 100b, channel "B" is used and in system 100c, channel "C" is used as the cordless communication link. Additionally, in system 100d, channel "A" is reused, and in system 100e, channel "B" is reused, without any interference or cross talk with systems 100a and 100b respectively. Because of the availability of multiple independent channels, the immediately adjacent units do not interfere with each other.

Additionally, because of the rapid decay of MI fields with distance, systems using the same channel (e.g., systems 100a, 100d each use channel "A") can be used in reasonably close proximity. While each of these features allows for the use of more systems in a confined area, the combination of these features further facilitates high user density applications, such as call centers, reservations centers, switchboards, and the like.

It is understood that the number of available channels is not limited to three (A, B, C) as indicated in FIG. 1B. Additionally, in the preferred embodiment the full duplex cordless communication link comprises two channels within the available spectrum, one channel for transmitting signals from a BU 110 to its RU 120, the other for the transmission of signals in the opposite direction. Thus, the channel designated as channel "A" would comprise channels A_1 and A_2. The preferred operating frequencies and channel allocations are described further below with reference to FIGs. 4A-D.

As illustrated in FIG. 1B, each of the cordless audio communication systems 100 can be connected to an automatic call distribution center 150. Referring now to FIG. 1C, an exemplary conventional automatic call distribution center 150 is shown. The automatic call distribution center 150 (ACD 150) is used to manage and distribute calls among the various systems 100a, 100b, 100c, 100d, 100e in multi-user situations such as high user density environments. The ACD 150 includes an agent availability module 175. The agent availability module 175 is used to determine whether users corresponding to the various systems 100a, 100b, 100c, 100d, 100e are available to take calls. For example, the person working at the station for system 100a might want to take a break. The agent availability module 175 is arranged to receive a signal that indicates that system 100a (or any system 100 in the environment) is no longer available to take calls. This signal can be referred to as an agent-unavailable signal. Once the agent-unavailable signal is received for a system (e.g. system 100a), the ACD 150 does not direct any further calls to that system (100a). When a system becomes available, such as when a person returns from a break, an agent-available signal is

provided to the ACD 150 agent availability module 175, which logs the signal and prompts the ACD 150 to allow calls to go to the available system 100.

REMOTE UNIT

Referring now to the block diagram of FIG. 2, an embodiment of a RU 120 in accordance with the present invention includes an audio interface 202, transceiver circuitry 204, modulation control circuitry 206, power management circuitry 208, a battery 210, aerial circuitry 212, light emitting diodes (LEDs) 214, a microcontroller 216, and non-volatile memory 228 (such as a NOVRAM or EEPROM). Additionally provided are hook switch 218, a mute switch 220, and a receive volume control 222, as well as ports P1 and P2 to interface with other devices. Further provided are an agent not available (ANA) switch 224 and an ANA disable/enable switch 226.

The operations of the RU 120 are controlled by the microcontroller 216. The microcontroller includes firmware stored in ROM 250, such as illustrated in FIG. 13. Generally, the RU functions are directed by the microcontroller based upon the firmware instructions. Fig. 13 illustrates exemplary firmware modules 260, 270, 280, 290, 292, 294, 296 for certain specific aspects of the present invention. Specifically, an operating frequency module 260, a link maintenance and security module 270, an ANA module 280, a background communication module 290, a power conservation module 292, a reset module 294, and a supervisory module 296 are shown. The link maintenance and security module 270 includes a range monitoring module 272, a code verification module 274 and a link managing module 276. The ANA module 280 includes an availability status module 282 a timing module 284 and an ANA signal generating module 286. The microcontroller 216 operates in conjunction with the remaining RU 120 hardware according to the instructions provided in firmware to perform the operating frequency, link maintenance and security, ANA, background communication, power conservation, supervisory, and resetting functions described further below.

The ordinarily skilled artisan will recognize the various modular arrangements for a firmware implementation once instructed according to the present invention, and will recognize the many variations from the exemplary modular breakdown of FIG. 13 (and FIG. 12 for the BU) that are available. It is understood that, although certain aspects of the present invention are preferably provided in firmware, software or a combination of the two may be provided.

Referring again to FIG. 2, the RU 120 receives audio signals from the headset 160 and passes them through a cordless link to the BU 110. More specifically, the RU 120 receives an electrical analog audio signal through a corded connection at port P1 between the headset 160 and the RU 120, amplifies the audio signal as needed, frequency modulates a carrier frequency using the audio signal, and uses this modulated signal to drive aerials 212 and transmit the signal using MI fields. The RU 120 signal transmission frequency is predetermined for appropriate receipt of the signal by its BU 110. Signals are also received by the RU 120 (from the BU 110) and are provided as audio signals to the headset 160. The RU 120 aerials (in the aerial circuitry 212) are dynamically tuned to the signal transmission frequency of the BU 110 by the microcontroller 216 and thus receive the FM carrier frequency signal transmitted from the BU 110. This received FM signal is demodulated by modulation control circuitry 206 which provides the audio signal, amplified if necessary, to the headset 160 earphones through a corded connection at port P1.

The hook switch 218 is coupled to the microcontroller 216 and allows the user to remotely connect and disconnect with the host system 130. For example, where the host system 130 is a telephone system, the hook switch 218 is used to accept calls (i.e. to "pick up" the call) and to terminate calls (i.e. to "hang up" the call), without the RU 120 being physically engaged with the BU 110. The hook switch 218 is a conventional toggle type switch that is used both for call acceptance and termination. Preferably, the hook switch 218 activates a control line that causes the microcontroller 216 to insert appropriate coded control tones into the modulated MI signal. After receipt and

demodulation by the BU 110, the coded control tones are interpreted as a "hook switch" command causing the state of the switch to change.

The audio interface 202 is coupled to the headset 160, the transceiver circuitry 204, the mute 220 control, and the volume control 222. The audio interface 202 comprises a pre-amplifier and a power output stage. The pre-amplifier receives signals from the headset microphone and outputs them to the transceiver circuitry 204, and the power output stage receives signals from the transceiver circuitry 204 and outputs them to the headset earphones. The receive volume control 222 determines the level of the signal provided to the headset earphones by controlling the output stage. The mute switch 220 allows the user to isolate the channel by terminating the connection of the headset microphone to the transceiver circuitry 204. Particularly, actuation of the mute switch 220 prevents the audio from the microphone from modulating the carrier frequency. In one embodiment, the mute switch 220 stops the audio, but still transmits the carrier. In an alternative embodiment, the mute switch 220 can turn the RU transmitter off completely.

The transceiver circuitry 204 and modulation control circuitry 206 are coupled to the microcontroller 216 to control the amplification and modulation of signals to be transmitted from the RU 120, and the amplification and demodulation of received signals (such as from the BU 110). In the transceiver circuitry 204, automatic gain control (AGC) is preferably applied to the headset user's voice signal prior to frequency modulation. This allows the amplitude of the signal to be limited to control the maximum frequency deviation in the resultant signal, thereby containing the modulated signal within an allocated bandwidth.

Additionally, the transceiver circuitry 204 includes a multiplexer that can be used to isolate the circuitry 204 from the audio interface 202. This allows the transmission of control signals, such as audio tones, between the BU 110 and RU 120 without interference that would be produced by the voices of the caller and user. The control signals provide various control functions and are described further below. The control signals to be transmitted by the RU 120 are provided by the microcontroller 216

to the transceiver circuitry 204. They can be stored in non-volatile memory in conventional fashion.

The modulation circuitry 206 comprises a standard FM radio transmit and receive circuit incorporating a dual phase locked loop (PLL) synthesizer which sets the transmit and receive channel frequencies under the control of the microcontroller 216. Preferably, the circuit also includes a Received Signal Strength Indicator (RSSI) which can be used to determine the strength of received signals.

The aerial circuitry 212 includes one or more aerials (e.g., aerial Tx1, Rx1) and associated circuitry. The associated circuitry is arranged to drive and tune the transmit aerial (Tx1) and to tune the receive aerial (Rx1). Additionally, the associated circuitry amplifies signals for transmission by the transmit aerial and amplifies signals received by the receive aerial. The associated circuitry interfaces the aerials (Tx1, Rx1) with the modulation circuitry 206 and the microcontroller 216.

The aerial circuitry 212 transmits and receives radio frequency signals. The aerial (Tx1, Rx1) may be singular, or, alternatively, may comprise a plurality of aerials, such as one for transmitting and a second one for receiving. The aerials (Tx1, Rx1) can be provided as set forth in copending application serial number 08/742,337, filed on November 1, 1996 and entitled "Aerial Arrays for Inductive Communication Systems," the entire contents of which are hereby incorporated by reference. Preferably, the aerials comprise separate aerials for respectively transmitting and receiving MI signals, and which provide zero mutual inductance so that the transmitted signal does not couple to the received signal.

Signals are provided from the modulation circuitry to the aerial circuitry 212 which includes a transmit aerial (Tx1) . Preferably, the aerial circuitry 212 includes conventional signal amplification circuitry with control inputs so that amplification can be controlled and disabled. The transmit aerial (Tx1) appears as an inductor in conjunction with the aerial transmit circuitry 226. The transmit aerial (Tx1) is driven with a sinusoidal signal that, along with the signal selection features of the RU 120, inherently tunes the aerial (Tx1) to the transmission frequency. The aerial circuitry also

facilitates adjustment of the power which is used to transmit signals from the RU 120, preferably by varying the amplitude of the voltage signal applied to the aerial Tx1.

The aerial circuitry 212 also includes a receive aerial (Rx1) and associated circuitry for receiving MI signals and providing them to the modulation circuitry 206. The aerial receive circuitry 236 allows the receive aerial (Rx1) to operate in resonant mode that bandpass filters the received MI signal. As with the transmit aerial (Tx1), the receive aerial (Rx1) appears as an inductor in connection with the aerial receive circuitry 236. Preferably, a resonant circuit is provided that includes the inherent inductance of the receive aerial (Rx1) and an additional circuit element that can be varied in an analog or digital manner (continuous or stepped).

Referring to the circuit schematic of Fig. 9, exemplary aerial circuitry 212 comprises a transmit aerial (Tx1) and a receive aerial (Rx1). Associated with the transmit aerial is circuitry for driving and tuning the transmit aerial including a transformer 910, an amplifier 905, a resistor 915, and a variable capacitor 920. Associated with the receive aerial is circuitry for tuning and amplifying signals received by the RU 120, including a receive amplifier 925 and a variable capacitor 930. The variable capacitors 920, 930 can be a voltage variable capacitor (VARICAP) that varies its capacitance based upon a voltage level from the microcontroller 216 (which includes a digital to analog converter for providing the voltage level). The variable capacitors 920, 930 can also be a bank of capacitors that are selectively enabled to provide the variable capacitance. In the second instance, the variable capacitance is controlled by control signals provided by the microcontroller 216. For the transmit aerial (Tx1), the variable capacitor 920 is in parallel with resistor 915 and is connected with the transmit aerial (Tx1) to form a circuit having a resonant frequency dependent upon the value of variable capacitor 920. The circuitry can be used to tune the transmit aerial (Tx1) according to the desired operating frequency. In conventional fashion, the amplifier provides signals from the modulation circuitry 206 to the transmit aerial (Tx1) through a transformer 910. The receive aerial (Rx1) is connected in parallel with the variable capacitor 930, forming a resonant circuit that varies dependent upon the

value of the variable capacitor 930. This allows the receive aerial to be tuned or adjusted to correspond to a bandwidth, within a channel, over which communication is sought. Signals received by the receive aerial (Rx1) are provided to the modulation circuitry 206 through a conventional amplifier 925.

With the preferred features of a resonant receive aerial (Rx1) operational mode and orthogonal transmit (Tx1) and receive (Rx1) aerials having no substantial mutual inductance, relatively simple circuitry performs the functions of both the duplex and channel filter in a conventional radio (propagating wave) FM duplex system.

The RU 120 is powered by a rechargeable battery 210. A port P2 is provided for interfacing with the BU 110 to charge the battery 210 under the control of the power management circuitry 208. This circuitry 208 also regulates power provided to the other functional modules, such as the transceiver 204 and modulation 206 circuitry, as well as to the microcontroller 216. The power management circuitry 208 also monitors the battery condition and provides an indication as such to the microcontroller 216. For example, when the battery 210 is low (i.e. near complete discharge), indication can be made to the microcontroller 216.

The microcontroller 216 provides output to the LEDs 312 for various functions, such as to indicate the activation of the mute condition and the detection of the battery low condition. In an embodiment, the microcontroller 216 can coordinate the functions of the unit 110 and provide non-volatile storage for the channel selection code, the security code and system calibration data. The non-volatile memory 228 can also be used to store information.

BASE UNIT

Referring to the block diagram of FIG. 3, an embodiment of a BU 110 in accordance with the present invention includes a headset/handset switch 302, configuration switch 304, transceiver circuitry 306, modulation control circuitry 308, power management circuitry 310, light emitting diodes 312 (LEDs), microcontroller 314, non-volatile memory 318, and aerial circuitry 316. Additionally, various ports P2-P8 are provided to interface with other devices.

As with the RU 120, the operations of the BU 110 are controlled by the microcontroller 316. The microcontroller 316 includes firmware stored in ROM 350, such as illustrated in FIG. 12. Generally, the BU functions are directed by the microcontroller 316 based upon the firmware instructions. Fig. 12 illustrates exemplary firmware modules 360, 370, 380 for certain specific aspects of the present invention. An operating frequency module 360, a link security module 370, an ANA module 380, a background communication module 390, a power conservation module 392 and a reset module 394 are shown. The operating frequency module 360 includes a channel allocation module 362, an interference assessment module 364 and a channel relocation module 366. The link security module 370 includes a security code verification module 372 and a code update module 374. The ANA module 380 includes an availability status module 382, a timing module 384 and an ANA signal generating module 386. The microcontroller 314 operates in conjunction with the remaining BU 110 hardware according to the instructions provided in firmware to perform the operating frequency, link maintenance and security, ANA, background communication, power conservation, and resetting functions described further below.

Referring again to FIG. 3, some host systems 130 may include a dedicated headset interface socket which allows direct connection to the BU 110, without disconnection of the host system 130 handset from the host handset interface. Specifically, where a dedicated headset interface (not shown) is provided, connection is made directly to the unit 110 through port P4. Alternatively, an arrangement without a dedicated interface can be provided such as is shown in FIG. 3. For this arrangement, the host handset 140 is disconnected from the host handset interface 142 of the host system 130. The BU 110 is coupled to the host handset interface 142 through port P4, while the host handset 140 is coupled to port P5. The headset/handset switch 302 is used to determine whether signals are transmitted and received using the host handset 140 or the headset 160. If the handset 140 is selected, conventional signal transmission through a wired connection is provided. If the headset 160 is selected, then signals are routed through the cordless communications link between the base 110 and remote 120

units to facilitate communication. For non-standardized host handset interface 142 pin allocations, the configuration switch 304 is provided to match the particular pin allocation to the input and output channels of the transmit and receive circuitry 306 of the unit.

The transceiver circuitry 306 is coupled to the configuration switch 304 and passes audio signals to and from the host system 130. For example, where the host system 130 is a telephone system, the audio signals comprise the conversation between the headset 160 user and the caller on the other end. Additionally, telephone calls can be managed and distributed by an ACD 150 system such as that shown and described with reference to FIGs. 1B and 1C. Similar to the RU 120 configuration, the transceiver circuitry 306 and modulation control circuitry 308 are coupled to the microcontroller 314 and control the amplification and modulation of signals to be transmitted from the BU 110, and the amplification and demodulation of received signals (such as from the RU 120). In addition to passing audio signals to and from the host system 130, controlling tones can be passed between the BU and RU microcontrollers 216, 314. Controlling tones can also be used to provide control signals from the RU 120 through the BU 110 to the ACD 150. Thus, the ACD 150 can manage and distribute calls according to the information transmitted over a cordless link between the BU 110 and RU 120.

The modulation circuitry 308 is similar to the circuitry 206 in the RU 120, but the frequency synthesizer in the receive circuits spans the total frequency band used for the communication link, 2 to 30 MHz for the exemplary operating frequency embodiment. This allows the receiver to detect the operation of other units and the presence of interference anywhere in the band, as required for the channel allocation and selection function to be described. Fig. 10 illustrates the spectral environment of a BU 110 aerial 316 between 6.96 and 7.04 MHz. Two instances of VDU interference, and the signal from an RU 120 at approximately 1 meter range appear in the shown spectrum. If necessary, the operating frequency of the RU 120 can be adjusted, preferably as directed by the BU 110, to avoid interfering signal sources.

As with the RU 120, the BU 110 aerial circuitry 316 can comprise a singular, or alternatively, a plurality of aerials for respectively transmitting and receiving MI signals. Additionally, a series of candidate aerials can be provided, with operating frequency and other parameter dependent (e.g., amount of interference, number of units in the local operating environment, intended operating range) selection of the actually implemented aerials. Such aerial selection features can also be provided in the RU 120. Various arrangements and configurations can be provided for the BU 110 and RU 120 aerials, such as those in the copending application entitled "Aerial Arrays for Inductive Communication Systems," Ser. No. 08/742,337, filed November 1, 1996 by Peter M. Flowerdew. For driving and tuning the transmit aerial and tuning and amplifying the receive aerial, the aerial circuitry 316 is essentially similar to the RU 120 aerial circuitry 212 illustrated in FIG. 9.

The modulation circuitry 308 also includes RSSI circuitry. The aerial circuitry 316, modulation circuitry 308, and RSSI circuitry communicate with the microcontroller 314 to provide features such as channel allocation and selection, as well as interference avoidance. Interference from adjacent units (those other than the RU 120 that the BU 110 should be properly communicating with) and other sources (such as VDUs) is distinguished with the modulation circuitry 308 in conjunction with the microcontroller 314. Preferably signal strength is compared before and after it is demodulated to distinguish interference from adjacent units and interference from other sources. An unmodulated signal (e.g., noise from a VDU) would show a large difference in signal strength before and after demodulation. A modulated signal (e.g. from an RU) would show a small difference before and after demodulation. Signal strength can be determined by a conventional peak detector, and a conventional comparator can be used to determine whether the difference in signal strength before and after demodulation exceeds a predetermined threshold. The BU 110 can also enter into a high sensitivity mode wherein the RU 120 to BU 110 transmitter is disabled and the gain on the BU 110 receive aerial is adjusted to its maximum.

As indicated with reference to FIG. 1, the BU 110 is powered through the power adapter 150 which can be connected, for example, to a standard household power supply. Power is distributed by the power management circuitry 310, which also controls RU 120 battery 210 charging. Port P6 interfaces with RU 120 port P2 to facilitate charging.

The state of the power supply, battery charging, the selection of the handset or headset and the operation of the mute function can be signaled to the user by LEDs 312 as directed by the microcontroller 314. The microcontroller 314 also co-ordinates the functions of the unit and implements non-volatile storage for the channel selection code, the security code and system calibration data.

Because of the physically larger size of the BU it can be provided with more efficient aerials than the RU. This provides a greater transmission range, which can be used for the control protocol when the RU goes out of range, and a greater receive sensitivity, which can be used to allow the base to scan its electromagnetic environment to avoid interference and occupied channels during channel allocation and selection.

The BU 110 also has a channel reset button 318 for changing channel allocation, when desired. Channel reset activation causes a sweep of the available spectrum to determine a desired, open communication channel. Preferably, the scan proceeds along the spectrum from its existing allocation and finds the next unoccupied channel. The security code is also changed by actuation of a button and is exchanged with the RU 120. Thus, the channel allocation and the security code change related to inter-system interference can be addressed by user action. In an alternative embodiment, button 318 can be used for changing both the channel allocation and the security code. In an embodiment, the channel reset switch will only function when a matched RU is docked to its BU.

In the preferred embodiment the BU 110 and RU 120 are physically in electrical contact, for the prime purposes of recharging the RU batteries, when the system 100 is out of use. When the units 110, 120 are docked, their respective microcontrollers can

communicate via a serial link. Thus, during docking, channel allocation, security and other described functions may be undertaken without requiring cordless signal transmission and receipt.

OPERATING FREQUENCIES

As indicated above, the cordless link between the BU 110 and RU 120 units is provided by frequency modulated MI signals. Such signals will provide cordless operation with a usable range typically less than 30 ft (10 m) at frequencies under 30 MHz. Because of existing regulatory controls, frequencies between 2 MHz and 30 MHz are of prime interest and practical embodiments are likely to use the band 2 to 10 MHz. This is because the approximate cube law decay occurs in the near field, becoming first square law and then linear with increasing distance, and the near field comes too close above 10 MHz. The cube law holds to a range of about 6 feet at frequencies below 10 MHz.

Although multiple channels are provided, their number will be limited by the available bandwidth and other demands, such as the desired signal quality. The channel re-use distance (RUD) corresponds to the minimum desired separation between units using the same channel. Objective criteria can be implemented to determine the RUD, such as calculations of the expected interference between units operating at the same frequency as a function of distance. The RUD can be modified by a "safety factor" type multiplier to further avoid any interference. Additionally, subjective criteria, such as, for example, a demand for extremely high quality, can be used in the RUD determination, again in the form of a multiplier. Since the RUD determines the minimum separation of certain units, there is a direct relation between the allowable user density and the RUD. Because the number of users increases as the square of range and the field decays approximately as the cube of range, MI can accommodate the highest practical user densities. The RUD is preferably determined by the highest operating frequency that the units will operated at (e.g., in a 2-10 MHz system, the highest operating frequency would be 10 MHz).

Referring now to the graph of FIG. 11A and the schematic of FIG. 11B, an exemplary determination of the operating range R and the RUD is illustrated. The graph of FIG. 11A illustrates the signal strength versus the range for a signal having a cube law decay. It is understood that signals having a square law or linear decay would have a different curve than that shown for the cube law decay. It is also understood that the curve for signal strength versus range will vary dependent upon the frequency (e.g. the maximum operating frequency). The determination of the operating range R will also vary dependent upon the specified minimum level of signal strength S. Thus, the graph of FIG. 11A is merely provided to illustrate how the operating range R and RUD can be determined. The signal strength S is the specified minimum signal strength and correlates to the maximum operating range R. When an RU is separated from its associated BU by more than R, it can be considered Out Of Range (OOR). There is also a specified maximum signal level S1 that can be received from other units. The corresponding range for the signal level S1 is range R1. Referring to FIG. 11B, the RUD is the operating range R plus the allowable interfering signal range R1.

In conventional radio frequency FM signal transmission, a number of channels are located sequentially across a continuum of the available spectrum. However, at the power levels allowed for unlicensed operation in the 2-30MHz range, sequential bandwidth occupation can be ineffective because of the possibility of the presence of harmonically related signals produced by the deflection coils in video display units (VDUs) and other equipment.

Preferably, in accordance with an aspect of the present invention, the channel occupied bandwidth can be relocated to avoid interfering tones without interfering with other channels in the available spectrum. Referring to the graphical diagram of FIG. 4A, channels 1, 2 and 3 are shown, each channel having a channel occupied bandwidth. Additionally, the presence of an interfering tone within the range of available frequencies is shown. If a sequential continuum were provided, the interfering tone would reside in the channel allocated bandwidth of channel 3,

rendering it unusable. If, however, the interfered channel 3 is moved, as indicated in FIG. 4A, its channel occupied bandwidth does not overlap with the interfering tone. Preferably, the channel center frequency corresponding to channel 3 is moved by a fraction of its allocated bandwidth to avoid the interfering tone. Although this technique can optimize the use of the available bandwidth, it can be difficult both to administer at installation and costly to implement. One reason for this is that, while channel relocation may avoid interfering tones, it can affect the allocation of surrounding channels. For example, a channel 4 (not shown) adjacent to channel 3 might also require relocation due to the relocation of channel 3.

In accordance with another aspect of the present invention, channel relocation that does not affect the allocation of surrounding channels is also provided. This second allocation scheme provides the benefit of the flexibility of relocation to avoid interfering tones while retaining deterministic occupation of the available spectrum. Referring now to the graphical diagram of FIG. 4B, a plurality of communication channels 401a, 401b, and 401c within an available spectrum are shown. Each channel 401 has bandwidth. Preferably the bandwidth of the channel 401 is the same for each channel, and corresponds to the bandwidth required to transmit signals using frequency modulated MI signals between the base 110 and remote 120 units. The spectrum then is divided into a plurality of predetermined channel slots 400, one for each channel 401. The bandwidth of each channel slot 400 is significantly wider than the occupied bandwidth of the channel 401. Thus, each channel 401 can be moved within its slot 400 by some fraction of the bandwidth of the slot 400. However, movement of a channel 401 does not require the relocation of adjacent channel slots 400, provided that the extents of the occupied bandwidth of the channel 401 remain within the channel slot 400.

Referring now to the graphical diagram of FIG. 4C, an exemplary channel slot 400 and occupied bandwidth for a channel 401 are illustrated. Preferably, the magnetic field is frequency modulated to transmit an audio signal typically having a base bandwidth of 300 Hz to 3.5 kHz. The desired speech quality in a conventional

telephone application requires a frequency deviation of approximately 10 kHz, giving a signal occupied bandwidth for a channel 401 of about 28 kHz. To allow for the finite rate of attenuation of practical filters, an allocated channel bandwidth of 35 kHz is feasible. This is placed within a channel slot 400 having a bandwidth of 75 kHz, within which the occupied bandwidth of the channel 401 can move in 5 kHz increments.

Referring now to the graphical diagram of FIG. 4D, an embodiment of channel allocation that provides full duplex communication between a BU 110 and RU 120 is shown. Preferably, the signals transmitted from base units 110 to remote units 120 reside in a first defined continuum 403 of the spectrum and those transmitted from remote units to base units reside in a second continuum 405. For example, channels A1, B1, and C1, which reside in a first continuum 403, are used to transmit signals from various base units 110A, 110B, 110C to remote units 120A, 120B, 120C while channels A2, B2 and C2, which reside in a second continuum 405 that is removed from the first, are used to transmit signals in the opposite direction. The channel slots A1, B1, C1, A2, B2, C2 are available for occupation. It is understood that there may be insufficient units in an installation to occupy all of the slots and some slots may be skipped because of interference.

Preferably a fixed frequency difference between the two frequencies used by the units 110, 120 in a system 100 which is equal to the total span of each available continuum is implemented. The fixed frequency difference means that the frequencies for each half of the full duplex path are in allocated pairs that are maximally separated in frequency according to the available spectrum. Thus, the nth channel slot in the band allocated for BU to RU communication is paired with the nth channel slot in the band allocated for RU to BU communication (e.g., A1 to A2, B1 to B2, C1 to C2). For example, with a lower band starting at 2 MHz and an upper band starting at 5MHz, a fixed 3 MHz difference between the signals transmitted and received by a unit would be provided. If the communication channel is tuned within a slot, such as to avoid an interfering signal, the frequency difference would still be approximately 3MHz and the principle of providing a fixed frequency difference would remain intact. The fixed

frequency difference minimizes the requirements for duplex and band-defining filters because it provides maximum separation of the two halves of the full duplex channel.

Although the fixed frequency difference is preferred, it is understood that the BU-RU and RU-BU channels may not be maximally separated. This may arise because of limitations on the available spectrum or because many channels include interference. Thus, a system may use channel B1 for the BU to RU channel and A2 for the RU to BU channel. Although such an arrangement is contemplated, it is noted that it would create the need for more complex signal filtering than with the preferred fixed frequency difference mode of operation.

Preferably, the receive aerials of each unit 110, 120 are resonant at the channel frequency such that, with the spectral separation described above, the duplex and channel filter functions are inherent in the aerial design. This simplifies the signal processing path and substantially eliminates the requirements for linear amplification before demodulation in an angle modulated system (a simple limiter or algorithmic amplifier can be provided where filtering is not needed, such as with the fixed frequency difference and resonant aerials).

Referring now to FIGs. 5A-C together, an exemplary allocation of channel slots is shown. Due to regulatory control not all the spectrum of interest is available, as indicated in FIG. 5A, wherein internationally reserved bands between 2 and 8 MHz are shown. With a 75kHz allocation, 33 channel slots remain available between 2 and 5 MHz, as shown in FIG. 5B, and preferably are used for transmitting audio signals from Bus 110 to Rus 120. Additionally, as shown in FIG. 5C, 36 channel slots remain available between 5 and 8 MHz and preferably are used for transmitting audio signals from Rus 120 to Bus 110.

Referring now to FIG. 12, an exemplary operating frequency module 360 for allocating channels, for adjusting channels and for avoiding interfering signals according to the above description is shown. The channel allocation module 362 determines the occupied bandwidth required for transmitting audio signals over a cordless link between the BU and RU. The occupied bandwidth can be a

predetermined parameter that is set in the module 362 or it can be provided elsewhere for access by the module 362, such as in the BU non-volatile memory. The channel allocation module 362 also allocates channels according to plurality of channel slots that are available as described above. Again the module 362 can include predetermined information or can access the BU non-volatile memory for the information about the availability of channels. Additionally, the BU and RU operating frequency modules are arranged to perform the various functions described regarding the BU, the RU and their operating frequencies as described above. For example, the BU operating frequency module 360 also provides the necessary instructions for causing the microcontroller 314 to signal the modulation circuitry 308 and aerial circuitry 316 in order to control the channel frequency of the signal to be transmitted and the reception frequency of the transmit and receive aerials. Similarly, referring to FIG. 13, the RU operating frequency module 260 instructs the RU microcontroller 216 to signal the modulation circuitry 206 and aerial circuitry 212 to control the transmission and reception frequency of the RU.

It is understood that the precise frequencies, bandwidths and modulation methods are not limited to those described in connection with the preferred embodiments.

LINK MAINTENANCE AND SECURITY

As previously described throughout, such as in connection with FIG. 1B above, cordless communication systems 100 used in accordance with the present invention can be effectively used in high user density applications. These applications require multiple, independent communication links which provide full duplex operation for a plurality of systems 100 operating in a confined area. Typically, users will travel around their environment with an operating RU 120. In these and other instances, the user may inadvertently enter the operating zone of other users on the same channel. Casual eavesdropping, or inadvertent talk-over could then occur in the absence of preventative security measures. The present invention provides security coding mechanisms to exclude this possibility.

Referring to FIGs. 12 and 13, the BU 110 security module 370 includes a security code verification module 372 and code update module 374 and the RU 120 link maintenance and security module 270 includes a code verification module 274 to implement the security code features.

An exemplary security code is an n-bit digital word. Preferably, the security code is 16 bits, which provides 65,536 different codes. In an embodiment with 32 channels, this provides over two million different code/channel combinations, which is more than sufficient for most high user density environments.

The BU 110 microcontroller 314 includes non-volatile memory for storing a security code, preferably in the form of a 16 bit pseudo-random word. The security code is held in the BU 110 and is transferred to the RU 120 via a serial connection when the units are docked. The RU 120 microcontroller 216 also is operatively connected to the non-volatile memory for storing the transferred security code. Since the security code is maintained in the BU 110, alternative RUs 120 can be programmed from the BU 110 (i.e. have the security code exchanged to them) when a first RU 120 is put out of use for replacement, repair or battery discharge. This is an enhancement to the field reliability of the system 100, and makes it possible to use any RU 120 with any BU 110 at any time, thereby increasing the flexibility and ease of maintenance of the units in the field.

Link maintenance includes a link closure and recovery protocol that preferably uses the security code features of the present invention. Referring to FIG. 13, the RU 110 link maintenance and security module 270 includes a range monitoring module 272 and a link managing module 276. The RU link maintenance and security module 270 uses the security code to perform a link closure and recovery protocol as described below. Among the functions performed by the link maintenance and security module 272 are those by the various modules shown in FIG. 13. Among other things, the code verification module 274 verifies a security code identifying the pairing between the RU 120 and its associated BU 110, the range monitoring module 272 determines when the RU 120 leaves its operating range, and the link managing module 276 disables the RU

from transmitting and receiving audio signals when the RU leaves the operating range for a predetermined amount of time. The link managing module 276 also enables audio communication over the cordless communications link between the BU and RU when the RU reenters the operating range and the security code is verified by the verification module 274.

Although the link closure and recovery protocol is described in connection with the RU 110, it is understood that similar functions may be performed by the BU 120.

The security code is encoded by discrete tones which represent one or more bits of the code. This allows the code to be communicated between the units 110, 120 as a series of tones. In one embodiment, 16 distinct tones are provided. Thus, each tone can represent four bits of the security key and the transmission of two tones in sequence affects the transfer of eight bits of information.

The entire security code may be transmitted from unit to unit. For example, for a 16-bit code, four tones may be transmitted from the remote unit 120 to the BU 110 for code verification. Also, utilizing the duplex capability of the system, an embodiment of the RU 120 transmits one half of the security code and the BU 110 transmits the other half for mutual verification. Referring to the schematic of FIG. 6 and continuing with the 16-bit example, this embodiments employs the transmission of two tones from the RU 120 to the BU 110 representative of the first half of the code and two tones from the BU 110 to the RU 120 representative of the other half of the code. After transmission of the tones, each unit verifies and signals to the other unit receipt of the expected information for mutual verification. In this way all sixteen bits of the key are validated in the shortest possible time.

In a further embodiment, when the BU 110 determines that the RU 120 is OOR, it periodically sends a sequence of tones that contain the 16-bit security ID. The corresponding matched RU 120 still monitors its RSSI. When the RU 120 determines that it is in the range of a BU 110 on the correct channel, it will listen for the message being sent from the BU 110. If the BU 110 is transmitting the correct 16-bit security ID, the RU 120 will detect this (e.g., by checking the transmitted ID against it own stored

security information), and will then enable its transmitter. The BU 110 will then detect the presence of the RU 120, will stop transmitting security information, and the audio full duplex link is made available.

Another embodiment allows for the BU 110 or RU 120 to be only sending or receiving "in-band" data communications at any particular moment in time. This would require the BU or the RU to indicate to the other unit that it wishes to use "in-band" communication. This indication could be made using a tone system placed inside or outside the audio bandwidth, preferably but not necessarily below 300 Hz (sub-audible).

The security code feature can be implemented to prevent communication with an intruding RU that uses the same channel as the intended RU. During operation the RSSI of the RU can be monitored to determine when it goes below a predetermined threshold that indicates the operating range R (e.g., when the RSSI goes below signal strength S, the RU is determined to be beyond the range R, see FIGs. 11A and 11B). The range monitoring module 272 is in communication with the RSSI so that it can determine when the RU leaves its operating range. According to the instructions provided by the link managing module 276, the user can be informed, such as through a beeping tone, that they are on the range boundary so that they can be given a predetermined amount of time to reenter the operating range. The predetermined amount of time is preferably long enough to prevent unnecessary communication link terminations, but short enough to prevent the user from walking to the zone of the next system on the same channel before shutdown occurs. If the predetermine amount of time lapses, then the RU is placed in a listen only mode. The user cannot transmit and therefore cannot talk over another user on the same frequency.

In one embodiment, the BU, as instructed by its security code verification module 372, continuously transmits an initial part of the security code. When an RU (any RU) enters the BU operating zone it receives the initial part of the security key which is received by the RU code verification module 274. If the BU initial part matches the code that the RU holds it transmits its part of the security key and awaits

acknowledgment from the BU. The BU receives the RU portion of the security code. If there is a match, the BU transmits an acknowledgment and opens the audio link. The RU receives the acknowledgment, gives a warning tone to the user, and opens the audio link. These functions can be performed according to the code verification module 274 in communication with the link managing module 276. The communications link between the BU and RU is thus reestablished.

An unintended RU will be unable to complete the necessary link acquisition (valid security code exchange) with the BU, and thus will not receive acknowledgment.

When the RU 120 is detected to be out of range, the audio channels between the RU 120 and its BU 110 are disabled. Preferably, the RSSI which is a measure of the MI signal strength and corresponding range indicator is used to determine when an RU goes out of range. If after a predetermined time, typically about 1 second, the MI signal is not regained, the RU 120 shuts down the transmitter portion of the aerial circuitry 212 and mutes the ability of the RU 120 headset 160 to receive audio. This prevents the RU 120 from transmitting to talk over other units and from receiving communication not intended for the RU. The security code feature prevents the RU 120 from being acknowledged by another BU. Preferably, this is done by isolating the headset 160 from the incoming signals. This is done in the transceiver circuitry 204 at the direction of the microcontroller 216 according to the instructions in the link maintenance and security module 270. Although the transmitter is shut down and the audio receive is muted, the RU 120 still can receive signals, demodulate them, and provide them to the microcontroller 216 through the transceiver circuitry 204. The BU 110 responds to the loss of signal by muting its output line to the caller. The whole audio channel bandwidth is now available for signaling purposes. The BU 110 can then initiate the link recovery protocol by transmitting the security code (or part of the security) pursuant to the security protocol.

When the RU 120 is within the range of the BU 110, i.e. during normal use, the security code does not need to be exchanged. In a multiple system environment all other systems 100 whose RUs 120 are being used within their operating zone or range

will not require the security code exchange. If the RU 120 moves out of and back into range within the predetermined time, the security protocol will not be invoked and the audio path will recover quickly from the receiver's auto-mute or squelch system. This feature enables the user to momentarily move out of the operating zone, whether intentionally or otherwise, and still maintain the communication link with the BU 110, without having to verify the security code, and thereby momentarily delay a conversation in progress.

Additionally, systems 100 operating on the same channel which are near each other (e.g., system 100a and 100d in FIG. 1B) will be prevented from interfering with or listening in on each other. Specifically, if a system RU 120d leaves its operating range it is disabled after the predetermined time period. Once this occurs, the transmitter remains disabled, and the audio receive muted, until the link recovery protocol and the security protocol indicate that the RU 120d can appropriately communicate with the BU 110. Specifically, the RU 120d will not operate until the security code in its memory is matched to a BU 110.

The affected RU 120d still receives signals and, thus, waits for receipt of a valid security code. Typically the only BU 110 transmitting a code will be the BU 100d that the RU 120d has just left. This feature solves the two key security problems. First, the RU 120d cannot interfere with any other one while it is carried around the work environment, because its transmitter is shut down, thereby preventing interference or cross-talk. Second, the RU 120d will detect MI signals from other base units 110, but none of these will be transmitting the valid security key held by the BU 120d and therefore will not un-mute the receive audio signal, thereby preventing the user from listening to other conversations. Thus, three conditions are required for a breach of security: the intruding user must be operating on the same channel, the intruding user must have the identical security code and both users must simultaneously be out of range of their base units.

When the user returns to within range of their base unit, the remote unit detects and validates the security key and then un-mutes the receive audio path and switches

its transmitter back on (at full power in a preferred embodiment) to re-establish the communication link.

The detection and validation of the security code requires a period of time, which may be unacceptable if the users simply moved momentarily out of the operating range, so a time interval must lapse before the security protocol is invoked.

In a typical embodiment the distance between the periphery of one operating zone to another used by the same channel would be at least about 3 meters. This distance can be walked in around 1.3 to 2.3 seconds. The time a user has between moving out of range and back into range without re-acquiring the security key is thus preferably typically be kept at about 1 second to ensure that they do not move into the working range of another unit before the link closure has occurred.

Where systems have greater or extra channel capacity the separation between systems operating on the same channel may be increased and the time interval before invoking the security protocol may be increased accordingly.

For certain high user density applications such as telephone call centers, the channel allocation and security code exchange are optimally provided at the time of installation. Alternatively, hardware determined channel allocation and security codes may be provided. Additionally, the allocations and codes may be reset on a periodic (e.g., daily) basis, or on demand, as appropriate to each applications.

The operating frequencies and the security key of a system may be held in non-volatile memory, particularly at the BU 110. For a multiple system 100 environment, initial values will typically be provided, so units installed at a single location would tend to have sequential channel slot allocations.

BACKGROUND COMMUNICATION and CONTROL FUNCTIONS

Background communication between the BU 110 and RU 120 is provided for various control functions. For example, such background communication is provided for security code verification (and possibly transfer), battery condition monitoring and RU 120 controls such as hook switch operations. The firmware instructions for the

background communication and control functions reside in the BU and RU background communication modules 290, 390.

Background communication can be undertaken using out-of-band signaling. For example, signals such as the tones used to encode the security code may be provided completely out of the audio band, or out of the used portion of the audio band. The out-of-band signals are then modulated and transmitted between the units 110, 120 along with the operational audio signals (e.g. the voices of the user and caller). Thus, signals for the background communication may be transmitted between the units 110, 120 using the same communications link as the audio signals, without interfering with the audio communications.

Alternatively, the signals for background communication may reside within the audio signal bandwidth. For this embodiment, the audio signals from the headset 160 user and the host system 130 are muted to prevent interference with the background communication. Specifically, in the RU 120, the transceiver 204 is isolated from the incoming audio signal (effectively muting it), and background communication such as the described security code encoding tone signals is provided from the microcontroller 216 to the transceiver 204. As with voice audio processing, the transceiver 204 passes the background communication to the modulation circuitry 206 and then to the aerial circuitry 212 for transmission. Thus, the signal transmission for the background communication is similar to normal audio signals transmission (e.g., the transmission of voice signals during normal operation). The receipt of background communication through the cordless link is also the similar to normal operation. Specifically, the connections to the headset 160 and host system 130 are muted or isolated and the background communication is received, demodulated, and passed to the microcontroller 216. The alternative transmission of normal audio and control audio is essentially a time division of the cordless communication link.

<u>POWER CONSERVATION</u>

During normal use the distance between the BU 110 and the RU 120 will vary, particularly where the user wanders within (or outside) the operating zone of the BU

110. The operating zone corresponds to a predetermined, maximum preferred distance between the BU 110 and the RU 120 during cordless communication. User density and signal quality criteria can be used to define the operating zone. Since the preferred signal power to link the BU 110 and RU 120 will vary as a cube of the distance between the units, it is an aspect of the preferred embodiment that the separation of the units is automatically monitored and the transmit power dynamically adjusted to maintain an adequate link while minimizing interference between adjacent systems and maximizing the operating time of battery powered units. The power monitoring and conservation features of the present invention are preferably performed by the instructions provided to the BU and RU by their respective power conservation modules 292, 392.

Various techniques can be used to maintain the appropriate signal transmission power. In one embodiment the gradient of the signal between a plurality of antennae at the BU 110 is used to compute the separation distance between the units, also referred to as the range. The range is then used to determine the appropriate transmission power. Referring to FIG. 7, the BU 110 receive aerials comprise first and second antennae separated by distance *d*. The range between the BU 110 and RU 120 is designated by the variable *r*. S1 and S2 represent the strength of the signal received at the first and second antennae, respectively. The range *r* is then estimated using the following equation.

$$\frac{S_1}{S_2} \cong k \frac{(r+d)^3}{r^3} \quad \text{(Eq. 1)}$$

The equation given is an approximation, and illustrates the principle of using the signal gradient to detect the range. More exact expressions may be derived or experimentally obtained.

Referring now to the illustration of FIG. 8, exemplary ranges and corresponding power levels are shown. The operating zone 800 of a system 100 comprises an inner zone 801 and an outer zone 803. The inner zone 801 represents the normal working range for a user seated at a work surface and using the RU 120 on their person, and

typically has a radius of 3 to 5 feet. Outside this zone 801, there is the outer zone 803, with a radius between 5 and 7 feet, in which the power is increased, by a factor of 3.5 for the situation indicated. When the user goes out of range (OOR) 805, a distinct audible tone may be provided to the user's headset to alert the user that she has exited the intended operating zone 800, and thereby give the user the opportunity to quickly re-enter the operating zone 800. After a predetermined time of OOR operation, the audio path is isolated and the link closure and recovery protocol is initiated, thereby severing the communication link between the RU 120 and the BU 110. Typically, the communication link will be reestablished under the security code exchange procedure.

Although a basic illustration showing ranges and corresponding power levels has been described, the operating zone 800 may be subdivided into more sub-zones. Additionally, a system with longer range may be provided. Additionally, although discrete sub-zones are shown, the power level may also be made to be a continuous function of range, with discrete drop off at a desired out of range distance.

The system 100 may also implement alternative methods for range detection and power level determination. For example, in one alternative, a tone outside the audio spectrum being used is monitored for signal quality through the transmission path between the BU 110 and RU 120 via background communication, and the transmit power is increased when the signal quality of the tone degrades below a predetermined level. Conventional signal to noise and distortion (SINAD) measurements may be used to determine the quality of signal transmission.

In another alternative, each unit, according to the instructions provided in its power conservation module 292, 392, monitors its Received Signal Strength Indicator (RSSI) and, by background communication transmission as previously described, signals the other unit when an increase of transmitter power is required. Preferably, the BU 110 transmits at a fixed power level, while the RU 120, being battery powered, monitors the received signal strength and from this, estimates the separation distance and adjusts transmit power as a function of the estimated range. However, in this or any of the alternatives, the transmit power of both units 110, 120 can be controlled.

AGENT NOT AVAILABLE (ANA)

The BU and RU are also configured to use the cordless communications link in conjunction with the agent availability function (e.g. agent availability module 175) of the telephone system (e.g., an ACD system). The agent availability function uses ANA signals (also known as a receiver availability function, which uses receiver not available signals) to determine whether or not calls should be directed to particular telephone lines. An ANA signal can be either an agent-available signal, which indicates that the telephone line should be considered to be available for calls, or the complementary agent-unavailable signal, which indicates that the telephone line should not be considered to be available for calls. In a corded headset system, an unavailability signal can originate from the disconnection of a physical, wired connection.

Preferably, in accordance with an embodiment of the present invention, the cordless link between the BU and RU is used in providing an agent-unavailable (or the complementary agent-available) signal to the telephone system to indicate whether the telephone line corresponding to the BU and RU should be considered available for further telephone calls. The RU microcontroller ROM 250 includes an ANA module 280 with an availability status module 282, a timing module 284 and an ANA signal generating module 286. Similarly, the BU microcontroller ROM includes an ANA module 380 including an availability status module 382, a timing module 384 and an ANA signal generating module 386. The BU or the RU, per the instructions in the ANA modules 280, 380, can independently use the cordless link between the BU and the RU to determine whether an agent-unavailable or its complementary signal should be generated. The BU 110 ANA signal generating module 386 includes instructions for causing the appropriate ANA signal to be transmitted to the telephone system (such as the ACD) through an ANA interface on the BU (port P8), or changes the signal path through the host handset interface.

In one embodiment, a characteristic of the cordless link between the RU and the BU is monitored to determine whether further calls should be directed to the RU.

Although the ANA module of the RU or a combination of the BU and RU ANA module 280, 380 could be used, this embodiment is described with reference to the BU ANA module 380 acting independently. The availability status module 382 includes instructions for determining the availability status of the RU by monitoring the cordless link between the BU and the RU. This can be done by determining when the RU goes out of range for a predetermined amount of time. The BU RSSI indicator can be used to measure the signal strength and the corresponding range. As described, when the signal strength goes below a certain level, the RU is determined to be out of range. Once this is detected and the signal strength does not return to a level indicative of in range operation, the availability status module 382 includes instructions for determining that the telephone line should be made unavailable to the telephone system and for generating a corresponding agent-unavailable signal. The timing module 384 is in communication with the availability status module 382 and provides the requisite timing intervals to the availability status module 382. Preferably, the predetermined amount of time for determining that an agent-unavailable signal will be generated is longer than the time period described in connection with the link closure and recovery protocol. This will allow the RU to reenter the operating range and establish recovery before the agent-unavailable signal is generated and sent to the telephone system. Alternatively, the ANA module 380 can include instructions to communicate with the link maintenance and security module 370 so that a recovery protocol can be attempted prior to generating the ANA signal. Upon a determination that an agent-unavailable signal should be generated, the availability status module 382 communicates the same to the ANA signal generating module 386. The ANA signal generating module 386 is in communication with the BU ANA interface (or an interface within the BU that is connected directly to the audio path/DC path of the host headset interface) which is arranged to transmit the agent not available signal to the telephone system (e.g., the ACD system) using a conventional wired link. According to this embodiment, the complementary agent-available signal can be generated and transmitted to the telephone system. Preferably,

this involves determining that an RU is validly within the operating range for a predetermined time period, followed by the generation of the availability signal and transmission of the same to the telephone system as described above.

In another embodiment, the RU ANA module 280 monitors the cordless link and determines whether and which ANA signals should be issued. Specifically, the availability status module 282 communicates with the timing module to determine whether the RU is out of range for a predetermined time period and can then prompt the ANA signal generating module 286 to provide an agent-unavailable or the complementary signal. The signal can then be transmitted from the RU to the BU, using the background communications features described above, as instructed by the ANA module 280. The ANA signal transmitted from the RU to the BU can cause the BU microcontroller 314 to transmit the ANA signal to the telephone system, or the BU ANA signal generating module 386 can include instructions for accomplishing the same result. The ordinarily skilled artisan will recognize the various alternatives.

The RU 110 also includes an ANA button 224 that allows the user to cause an agent-unavailable signal (or its complement, dependent upon the current availability status) to be transmitted from the RU to the BU using the cordless link between the units. For example, the user may be within the operating range and away from the base unit, but might still want to prevent future calls from being passed by the telephone system (such as the ACD) to his or her telephone line (the one connected to the BU). In that instance, the user can actuate the ANA button 224. This sends a signal to the microcontroller 216 which indicates that the user would like to send the ANA signal to the BU and then the telephone system. The availability status module includes instructions for receiving the signal prompted by actuation of the ANA button 224. When the availability status of the telephone line is "available," receipt of the ANA button 224 signal causes a determination to generate an agent unavailable signal. Similarly, when the availability status of the telephone line is "unavailable," receipt of the ANA button 224 signal causes a determination to generate the agent "available" signal. Alternatively, two separate switches could be provided for the ANA button 224

functions, one for agent-unavailable and the other for agent-available signal generation. Once the determination is made to generate the ANA signal, it is transmitted from the RU to the BU through the cordless link, and passed to the telephone system through the ANA interface.

In addition to instructions related to the monitoring of the operating range and receipt of the signal from the ANA button 224, the RU availability status module 282 includes instructions for determining that an agent-unavailable signal should be generated based upon other criteria, such as when the battery 210 capacity is low. Specifically, the RU availability status module 282 is in communication with the power management module 208 and thus receives signals indicative of the battery 210 status. When the battery power goes below a threshold level, the agent-unavailable signal is prompted as described above (e.g., by the availability status module in conjunction with the ANA signal generating module). The ordinarily skilled artisan will recognize the appropriate threshold level for determining whether to generate an agent-unavailable signal. Preferably, the threshold is the battery capacity that provides an estimated 5-20 minutes of remaining RU operation. In conjunction with the ANA module 280, the user can be warned, such as through a beeping tone, that the battery is low. The battery low warning to the user can precede the generation of the agent-unavailable signal so that the user can take alternative remedial action that allows calls to proceed to his or her station, such as using a hard-wired headset while recharging the RU.

Further, a "call in progress" signal can be used to determine whether to merely mute the RU pursuant to the link closure protocol, or to transmit an agent-unavailable signal from the RU to the BU, or to do both. Specifically, when a caller is on the line and the call in progress signal (received by the link maintenance and security module 270 and the ANA module 280) is provided, the link closure protocol (muting the transmitter) might be used, but the generation of the agent-unavailable signal could be inhibited. Conversely, when a caller is not on the line according to the call in progress

signal, the functions for generating the agent-unavailable signal would not be inhibited.

An ANA disable/enable switch 226 is also provided to selectively enable and disable the generation of the agent-unavailable signal or its complement. Specifically, if ANA signal generation is currently enabled, the user can actuate the switch 226 to disable the signal generation, or vice-versa. When the ANA signal generation is disabled, an agent-unavailable signal will not be generated and transmitted to the BU even if the conditions for unavailability are present (such as out of range operation or low battery capacity as described above). For example, this allows the user to prevent the unavailability signal from being transmitted to the telephone system when the user knows that an out of range condition will be transient in nature.

In alternative embodiments, the BU 110 can include switches analogous to either or both the ANA button 224 and the ANA enable/disable button 226 described in connection with the RU 120. In those embodiments, the switches 224, 226 may or may not remain included on the RU 120. The BU 110 buttons could be arranged to communicate with the BU ANA module 380, and would not require transmission of signals over the cordless link between the BU and RU to cause an unconditional (i.e., not prompted by loss of link or other criteria, but by actuation of the BU ANA button) transmission of an ANA signal to the ACD 150, or to selectively enable or disable the generation of ANA signals.

CHANNEL RESET

The channel reset button 318 is provided so that a system 100 user can change the channel slot allocation on demand. This may be the case where interference is experienced by an individual unit in a multiple unit installation, or talk-over is experienced because two very proximate units are operating on the same channel. The channel reset modules 294, 394 of the BU and RU include instructions for causing the microcontrollers 216, 314 to carry out the reset protocol, such as when the channel reset protocol is initiated by actuation of the reset button 318. References to actions by the

BU or RU are actually undertaken by the microcontrollers 216, 314 according to the instructions provided in the modules. The respective RU and BU channel reset modules 294, 394 are in communication with their operating frequency modules 260, 360 and their link maintenance and security modules 270, 370, as well as various hardware in the RU and/or the BU in order to carry out the channel reset features. The

Preferably, when channel reset is activated, the reset module 394 instructs the microcontroller 314 to cause the BU 110 to enter a high receive sensitivity mode, whereby the operating frequencies of adjacent units and the spectral location of interfering sources can be detected.

The prime interfering source in the office environment is the scan coils of VDU's. This interference can be differentiated from signals originated by adjacent units, either by the fact that they are unmodulated or that they occur at harmonic intervals. The BU 110 can implement the microcontroller and modulation circuitry to determine whether a signal is an interfering one.

Upon activation of the channel reset function, a BU 110, per the instructions provided in the operating frequency module 360, scans the available spectrum, determines where the sources of interference reside, and allocates channels. Various techniques can be used to allocate channels, but preferably this is done by turning off the RU and BU transmitters, turning the gain on the BU to a maximum, setting the receiver synthesizer to the first channel to be examined, setting the control or voltage signals to the receive aerial to tune the receive aerial to the first channel to be examined, measuring the RSSI output, comparing the RSSI output to a threshold, and allocating the channel if the RSSI output indicates a pass (e.g., no interference), or incrementing the channel and repeating the allocation sequence for a fail (e.g. too much interference).

If a portion of a channel slot is available, the BU 110 determines whether the channel occupied bandwidth can reside within the channel slot by checking intervals corresponding to the occupied bandwidth. The BU 110 can indicate to the user when it

is unable to operate in the available spectrum, whether due to excessive interference or user density, allowing the user to take appropriate remedial action.

Having scanned the spectrum and determined an appropriate available channel slot and location within that slot, the BU 110 computes the transmit and receive frequencies that it will operate at, using the frequency offset between the first and second continuums for these frequencies. These frequencies are then transferred, by a direct metallic (e.g. serial interface) or cordless communication link to the RU 120, allowing it to set itself to the corresponding frequencies to complete the link.

The following sequence of events is initiated by actuation of the system reset button or buttons.

Security Code:

1. A security code is determined by the BU 110 microcontroller, preferably using pseudo random number generation.

2. The BU 110 transfers the security code to the RU 120 using the serial link that connects them when the RU 120 is docked.

Channel Reset:

3. The BU 110 scans both its receive and transmit spectrum for the presence of interference. A predetermined algorithm, such as a sequential progression through adjacent channels, is used to acquire an available channel slot. If necessary, the carrier frequency is fine adjusted, or relocated, within the channel slot to avoid interference.

4. The BU 110 configures its modulation circuitry for the determined transmit and receive frequencies. For example, where a PLL synthesizer is used, the synthesizer is set to the determined frequencies. The BU 110 then, via the serial interface, prompts the RU 120 to be configured to the corresponding frequencies.

5. The BU 110 prompts the RU 120 to tune its receive aerial to the BU transmitted signal, and a tone that encodes part of the security code is transmitted to the RU 120.

6. The RU 120 receives the tone, demodulates and decodes it, and then compares it to the previously stored security code, then re-transmits the tone back to the BU. This action is indicated to the BU via the serial link.

7. The BU 110 then tunes its receive aerial to the remote transmit signal, and then demodulates and confirms the validity of the tone.

8. As a final check that both the frequency and security code been correctly set the code is exchanged and verified over the air interface.

The sequence from step 4 is repeated each time power is applied to the base unit 120. When it detects a remote unit 110 being docked, the first action taken will be to check, via the serial link, that the remote unit 120 holds the appropriate frequency and security key data. If it does not, the RU can only be recharged until and unless the appropriate reset is initiated as just described.

Upon completion of the above steps, the user is given an indication, preferably visual or auditory, that the docking sequence has completed and the system is ready for use. The user can then remove the RU 120 from the BU 110 and attach it to their person. Signal strength variations may occur as the user becomes situated. To compensate for this, both units can operate at full transmit power for a predetermined period of time, typically about 1 minute, during the initial use period.

SUPERVISORY REMOTE UNIT

Particularly in certain high user density applications like call centers, there is typically a need for a second person to monitor calls for training, evaluation, quality control, or other purposes. A wired connection may be made to allow both the supervisor and the user to talk to the caller. For example, a standard Y cord at the connection between the RU 120 and the headset 160 may be used for supervision.

Preferably, however, the RU 120 is configured as a supervisory unit 120 to allow interdiction without wired connections. The RU 120 firmware includes a supervisory module 296 for carrying out these features. Preferably, the microcontroller 216 includes internal switching and control inputs that can be configured in the factory but which are not easily accessible to the RU 120 user (i.e., there is no switch on the

outside of the RU 120 to enable conversion of the RU 120 to a supervisory RU 120). The supervisory RU 120 is conceptually identical to the standard RU 120, but the supervisory RU 120 operates in a listen-only mode (it does not transmit), and does not require the security code in order to receive audio signals from the BUs 110. In order to do this, the portion of the RU 120 which isolates the audio signal path between the headset 160 and the incoming signal path (e.g. at the transceiver circuitry) upon OOR or improperly initiated operation is omitted or alternatively, manually deactivated by a user accessible switch. This allows the free receipt of signals throughout the available spectrum. In yet another embodiment, the supervisory RU 120 does include transmit circuitry.

Although signal can be freely received by the supervisory RU 120, there is still a need for tuning to the frequency or frequencies particular to the system 100 being supervised. The required frequency settings may be obtained by temporarily docking the supervisory RU 120 to the targeted BU 110. Since one primary use of the RU 120 is to listen to, rather than participate in, conversations, in this embodiment the RU 120 only requires receipt of the BU 110 to RU 120 transmit channel information. This allows interception of the caller's voice. The user's voice can be heard acoustically by the supervisor because the supervisor and user are present in the same area. Of course, when the RU 120' is docked to the particular BU 110, it can also capture both signal transmission channels and thus be configured to capture both ends of the conversation over the cordless communication channels.

Alternative methods of determining the operating frequencies (i.e. channels used) by targeted systems 100 may be provided. For example, tuning to the channel of a BU 110 may be achieved by entering its operating zone and activating a manual control to initiate a search for the next occupied channel. If the supervisor is within range of a number of BUs 110, repeated actuation of the control may cause them to be scanned in turn. This allows the supervisor to walk throughout the user environment, listening to the incoming calls for a plurality of different systems 100.

Certain embodiments of the present invention have been described in connection with a conventional telephone as the host system 130. Implementation with alternative systems 130 where a cordless MI voice or data link between two points can be used are within the scope of the invention. One example is implementation with mobile telephones. In this application the BU is connected to or integrated within a mobile telephone or other equivalent communications means. The RU is then preferably integrated within a lightweight headset thus providing cordless, hands-free use of the telephone. Typical situations where this capability would be of benefit are where the user is away from their normal operating environment and requires use of their hands for convenience, safety, or by law. For example, while driving a vehicle or working on equipment to instruction over the telephone. The telephone may be located in any convenient position within the operating range of the MI system.

In a preferred embodiment speech control of the host equipment for the BU would be provided. Additionally, by using the headset 160 in lieu of the mobile unit directly, any health concerns over long term exposure to the radio transmissions at the frequencies used by mobile telephones are lowered. Additionally, a computer system may be the host system 130. There, the BU 110 would interface with the computer rather than a telephone network, with appropriate modifications to the input lines. The computer would provide access to many digital audio functions which would include voice controlled software and telephony communication. Although voice communications are primarily described, various other information or data can be transmitted over the provided MI communication links. For example, particularly where a computer is the host system 130, various data, entered remotely, may be transmitted to the BU 110 for input to the computer. For example, digital control signals or digital data from a peripheral may be transmitted over the link. These and other alternatives to the preferred embodiments are provided for by the present invention which is limited only by the following claims.

CLAIMS

What is claimed is:

1. A method for full duplex cordless audio frequency communication between plural base and remote units operating in a high user density environment, the method comprising:

transmitting a first signal from a first base unit to a first remote unit using a first magnetic inductive signal having a first channel frequency and an approximately cubic decay rate;

transmitting a second signal from the first remote unit to the first base unit using a second magnetic inductive signal having a second channel frequency and an approximately cubic decay rate;

transmitting a third signal from a second base unit to a second remote unit using a third magnetic inductive signal having the first channel frequency; and

transmitting a fourth signal from the second remote unit to the first base unit using a fourth magnetic inductive signal having the second channel frequency.

2. The method of claim 1, further comprising:

transmitting a fifth signal from a third base unit to a third remote unit using a fifth magnetic inductive signal having a third channel frequency that is different from the first channel frequency; and

transmitting a sixth signal from the third remote unit to the third base unit using a sixth magnetic inductive signal having a fourth channel frequency that is different from the second channel frequency.

3. The method of claim 1, wherein the first and second channel frequencies are separate frequencies which are each in the range between about 2 MHz and about 10 MHz.

4. In a system including a base unit and a remote unit wherein a first audio signal is transmitted from the base unit to the remote unit and a second audio signal is transmitted from the remote unit to the base unit using a cordless link, a method for allocating communication channels so that interference may be avoided, the method comprising:

determining an occupied bandwidth required for transmitting audio signals over a cordless link between the base unit and the remote unit;

providing adjacent first and second channel slots, each slot having a bandwidth that exceeds the occupied bandwidth;

allocating the first channel to the first channel slot;

determining the presence of an interference signal at a frequency within the first channel slot; and

relocating the first channel within the first channel slot to avoid the interference signal without encroaching upon the boundaries of the second channel slot.

5. The method of claim 4, further comprising:

providing adjacent third and fourth channel slots, each slot having a bandwidth that exceeds the occupied bandwidth, the third channel slot having a fixed frequency difference from the first channel slot, the fourth channel slot having the fixed frequency difference from the second channel slot; and

allocating the second channel to the third channel slot to provide a substantially fixed frequency difference between the channels used to transmit the first and second signals.

6. For use in a system including a base unit and a remote unit wherein a first audio signal is transmitted from the base unit to the remote unit and a second audio signal is transmitted from the remote unit to the base unit using a cordless link, an apparatus for allocating communication channels so that interference may be avoided, the method comprising:

a channel allocation module, for determining an occupied bandwidth required for transmitting audio signals over a cordless link between the base unit and the remote unit, providing adjacent first and second channel slots, each slot having a bandwidth that exceeds the occupied bandwidth, and allocating the first channel to the first channel slot;

an interference assessment module, in communication with the channel allocation module, for determining the presence of an interference signal at a frequency within the first channel slot; and

a channel relocation module, for relocating the first channel within the first channel slot to avoid the interference signal without encroaching upon the boundaries of the second channel slot.

7. The apparatus of claim 6, wherein the channel allocation module is further arranged for providing adjacent third and fourth channel slots, each slot having a bandwidth that exceeds the occupied bandwidth, the third channel slot having a fixed frequency difference from the first channel slot, the fourth channel slot having the fixed frequency difference from the second channel slot, and for allocating the second channel to the third channel slot to provide a substantially fixed frequency difference between the channels used to transmit the first and second signals.

8. The method of claim 1, further comprising:

estimating a quality of the transmission of the second signal from the remote unit to the base unit;

adjusting the amount of power being used to transmit the second signal based upon the quality of the transmission.

9. The method of claim 8, wherein estimating a quality of the transmission comprises:

transmitting a test tone from the remote unit to the base unit;

receiving the test tone at the base unit and applying a quality assessment measurement to the received test tone.

10. The method of claim 8, wherein estimating a quality of the transmission comprises:

monitoring a received signal strength indicator of the base unit;

transmitting information pertaining to the received signal strength from the base unit to the remote unit.

11. In a system including a plurality of base units and a plurality of remote units wherein signals are transmitted between paired base and remote units using a cordless communications link over a predetermined operating range, a method for maintaining the security of the communications link, the method comprising:

providing a first remote unit with a security code identifying the pairing of the first remote unit with a first base unit;

disabling the first remote unit from transmitting and receiving audio signals when the first remote unit leaves the predetermined operating range for a predetermined amount of time; and

enabling the transmission and receipt of audio signals between the first remote unit and the first base unit when the first remote unit enters the predetermined operating range and the security code is verified.

12. The method of claim 11, further comprising:

providing a supervisory remote unit that does not require security code verification to receive the audio signals from any of the plurality of base units.

13. The method of claim 12, further comprising:

targeting a base unit from the plurality of base units

identifying a frequency that the targeted base unit uses to transmit signals; and

tuning the supervisory remote unit to receive the signals transmitted by the targeted base unit.

14. The method of claim 13, wherein the step of disabling the first remote unit comprises:

receiving signals transmitted over the cordless link to the first remote unit while preventing the first remote unit from providing audio signals to a headset, whereby the first remote unit does not pass audio signals to the first remote unit user but allows the first remote unit to receive control signals from the first base unit.

15. For use in a system including a plurality of base units and a plurality of remote units wherein signals are transmitted between paired base and remote units using a cordless communications link over a predetermined operating range, an apparatus for maintaining the security of the communications link comprising:

a code storage module, for providing a first remote unit with a security code identifying the pairing of the first remote unit with a first base unit;

a range monitoring module, for determining when the first remote unit leaves the predetermined operating range; and

a link managing module, in communication with the code storage module and the range monitoring module, for disabling the first

remote unit from transmitting and receiving audio signals when the first remote unit leaves the predetermined operating range for a predetermined amount of time, and for enabling the transmission and receipt of audio signals between the first remote unit and the first base unit when the first remote unit enters the predetermined operating range and the security code is verified.

16. In a communication system including a base unit and a remote unit associated with the base unit, the remote unit communicating with the base unit using a cordless link, the base unit communicatively coupled to a telephone system that provides a telephone line to the base unit, a method of indicating to the telephone system the availability status of the telephone line, the method comprising:

determining the availability status of the telephone line using the cordless link between the base unit and the remote unit;

generating an agent-unavailable signal when the step of determining the availability status of the telephone line indicates that the telephone line should be considered unavailable; and

electronically transmitting the agent-unavailable signal from the base unit to the telephone system to indicate to the telephone system that the telephone line is unavailable.

17. The method of claim 16, wherein the step of determining the availability status of the telephone line comprises:

determining when the remote unit leaves a predetermined operating range for the cordless link between the base unit and the remote unit;

determining whether a predetermined amount of time lapses before the remote unit reenters the predetermined operating range; and

determining that the telephone line should be considered unavailable when the remote unit leaves the predetermined operating range for the predetermined amount of time.

18. The method of claim 16, wherein the step of determining the availability status of the telephone line comprises:

actuating a switch at the remote unit that indicates whether the telephone line should be considered unavailable; and

transmitting the indication of whether the telephone line should be considered unavailable from the remote unit to the base unit using the cordless link.

19. For use in a communication system including a base unit and a remote unit associated with the base unit, the remote unit communicating with the base unit using a cordless link, the base unit communicatively coupled to a telephone system that provides a telephone line to the base unit, an apparatus for indicating to the telephone system the availability status of the telephone line, the apparatus comprising:

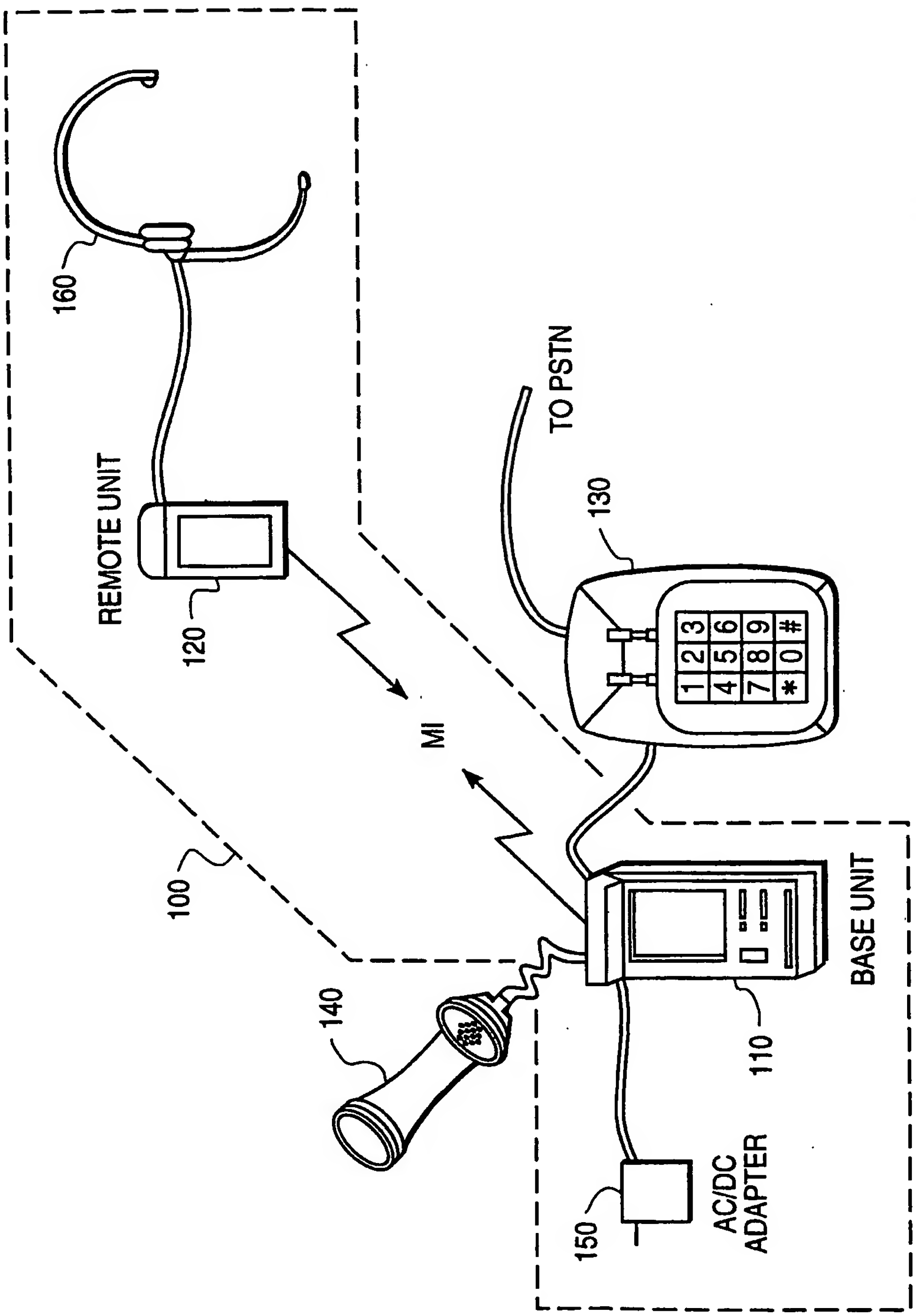
an availability status module, for determining the availability status of the telephone line using the cordless communications link between the base unit and the remote unit;

an ANA signal generating module, in communication with the availability status module, for generating an agent-unavailable signal when the availability status module determines that the telephone line should be considered unavailable; and

an interface, in communication with the ANA signal generating module, for electronically transmitting the agent-unavailable signal from the base unit to the telephone system to indicate to the telephone system that the telephone line is unavailable.

20. The apparatus of claim 19, wherein the availability status module determines the availability status by determining when the remote unit leaves a predetermined operating range for the cordless link between the base unit and the remote unit, determines whether a predetermined amount of time lapses before the remote unit reenters the predetermined operating range, and determines that the telephone line should be considered unavailable when the remote unit leaves the predetermined operating range for the predetermined amount of time.

21. The apparatus of claim 19, wherein the availability status module determines the availability status of the telephone line from a signal transmitted from the remote unit to the base unit using the cordless link.



160
REMOTE UNIT
120
MI
TO PSTN
130
100
140
110
BASE UNIT
150
AC/DC
ADAPTER
1 2 3
4 5 6
7 8 9
* 0 #

FIG. 1A

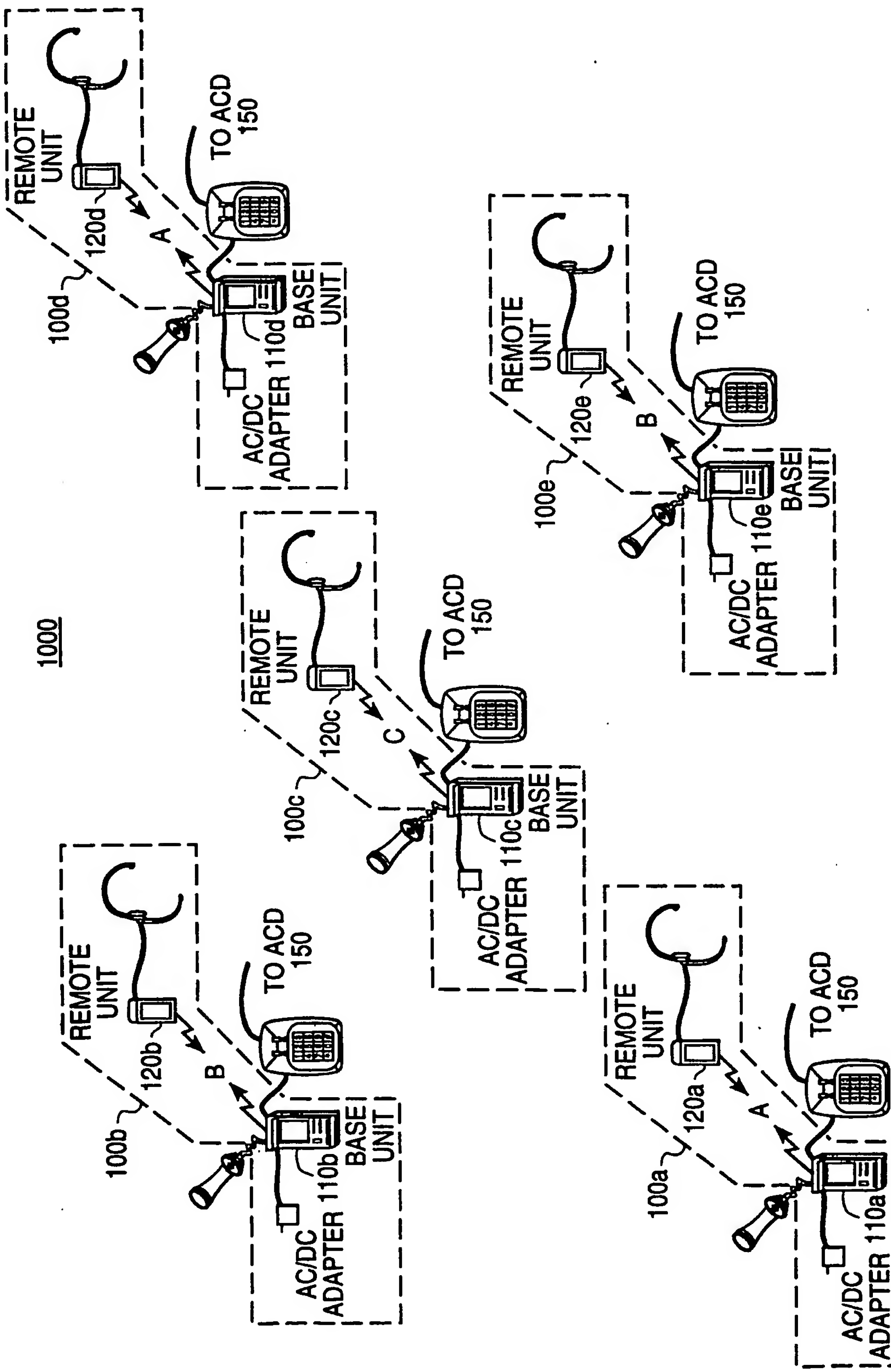

1000
REMOTE UNIT
120d
100d
A
TO ACD 150
BASE UNIT
110d
AC/DC ADAPTER
REMOTE UNIT
120e
100e
B
TO ACD 150
BASE UNIT
110e
AC/DC ADAPTER
REMOTE UNIT
120c
100c
C
TO ACD 150
BASE UNIT
110c
AC/DC ADAPTER
REMOTE UNIT
120b
100b
B
TO ACD 150
BASE UNIT
110b
AC/DC ADAPTER
REMOTE UNIT
120a
100a
A
TO ACD 150
BASE UNIT
110a
AC/DC ADAPTER

FIG. 1B

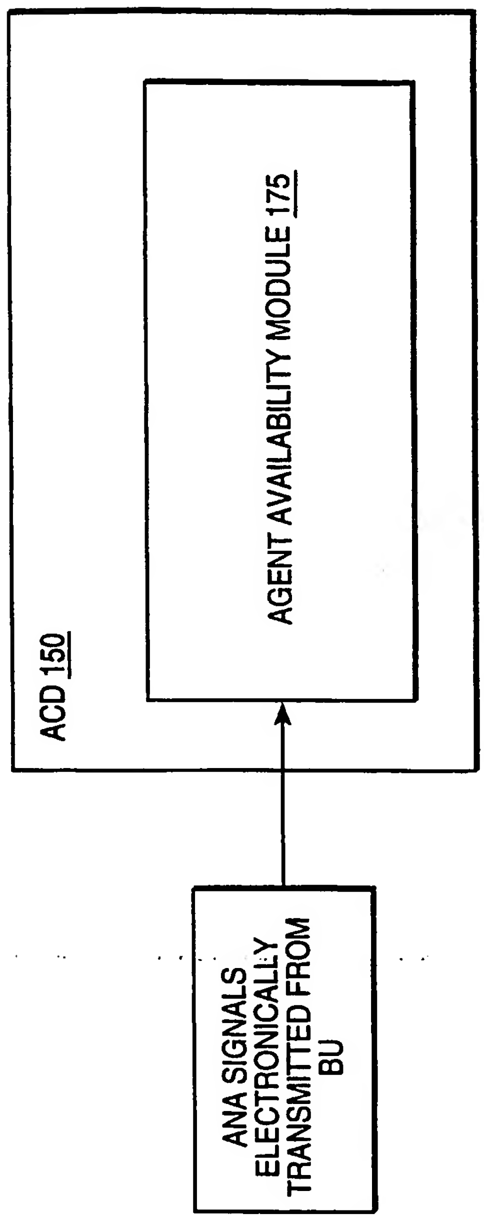

ACD 150
AGENT AVAILABILITY MODULE 175
ANA SIGNALS ELECTRONICALLY TRANSMITTED FROM BU

FIG. 1C

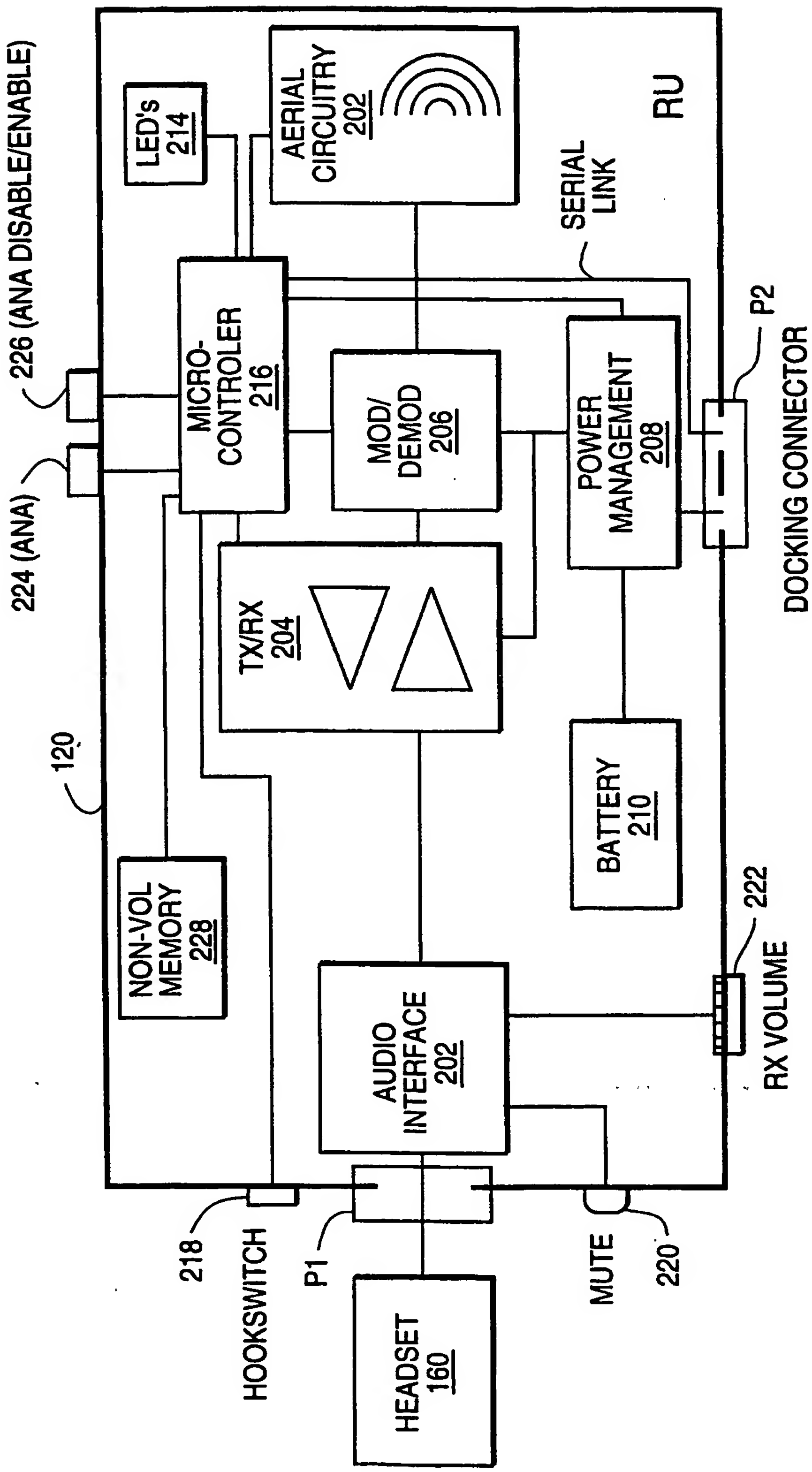

226 (ANA DISABLE/ENABLE)
224 (ANA)
LED's 214
AERIAL CIRCUITRY 202
RU
SERIAL LINK
MICRO-CONTROLER 216
MOD/ DEMOD 206
POWER MANAGEMENT 208
P2
DOCKING CONNECTOR
TX/RX 204
120
BATTERY 210
NON-VOL MEMORY 228
222
RX VOLUME
AUDIO INTERFACE 202
218
HOOKSWITCH
P1
MUTE
220
HEADSET 160

FIG. 2

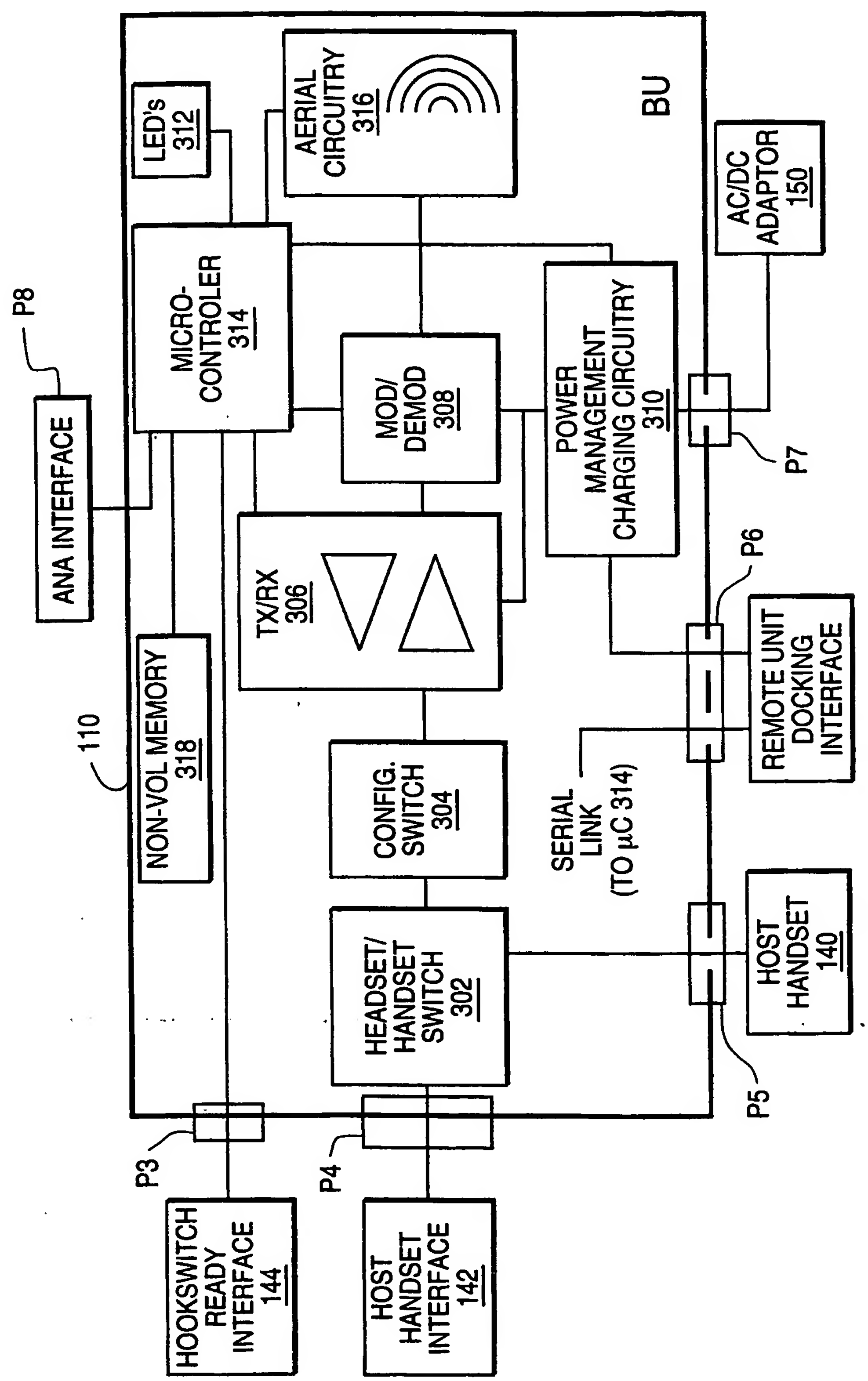
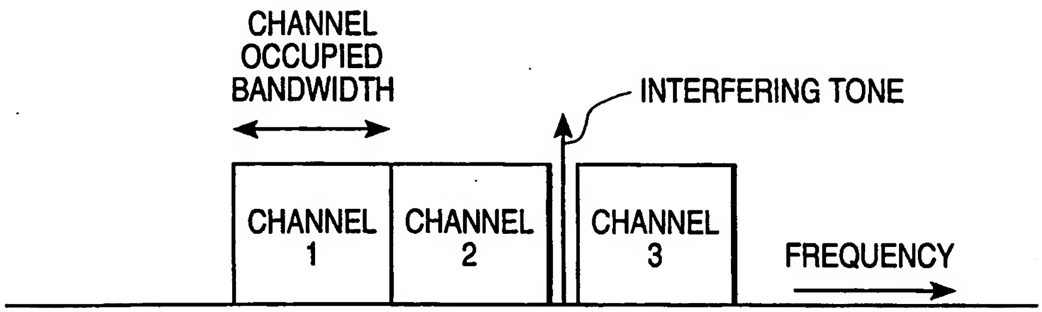

BU
LED's 312
AERIAL CIRCUITRY 316
AC/DC ADAPTOR 150
P8
ANA INTERFACE
MICRO-CONTROLER 314
MOD/ DEMOD 308
POWER MANAGEMENT CHARGING CIRCUITRY 310
P7
P6
TX/RX 306
NON-VOL MEMORY 318
110
REMOTE UNIT DOCKING INTERFACE
CONFIG. SWITCH 304
SERIAL LINK (TO μC 314)
HEADSET/ HANDSET SWITCH 302
HOST HANDSET 140
P5
P3
P4
HOOKSWITCH READY INTERFACE 144
HOST HANDSET INTERFACE 142

FIG. 3



CHANNEL SHIFTING

FIG. 4A

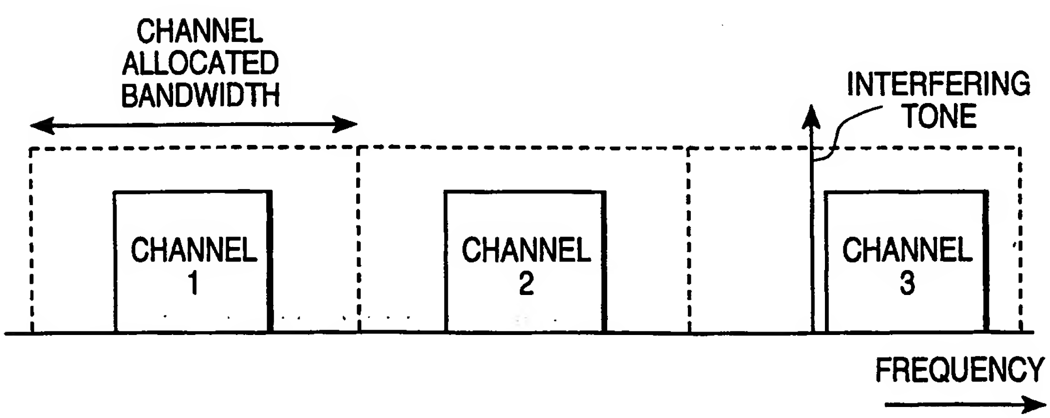


FIG. 4B

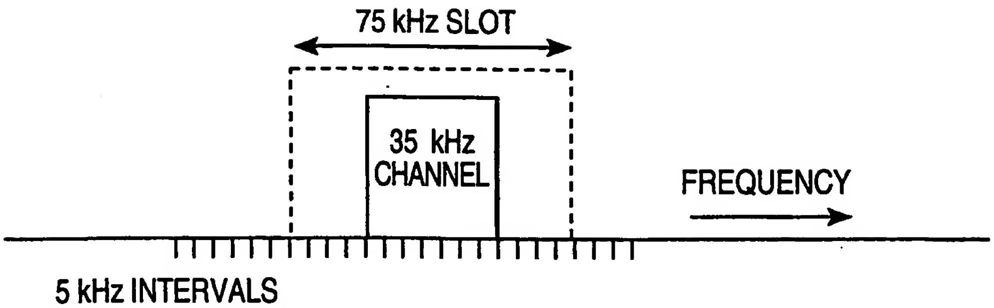

75 kHz SLOT
35 kHz CHANNEL
FREQUENCY
5 kHz INTERVALS

FIG. 4C

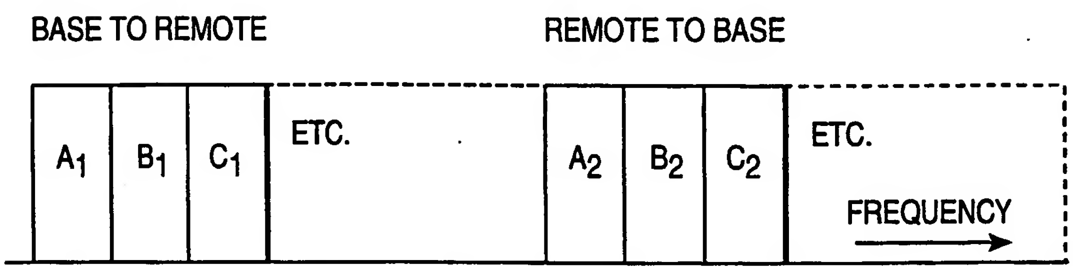

BASE TO REMOTE
REMOTE TO BASE
A_1
B_1
C_1
ETC.
A_2
B_2
C_2
ETC.
FREQUENCY

FIG. 4D

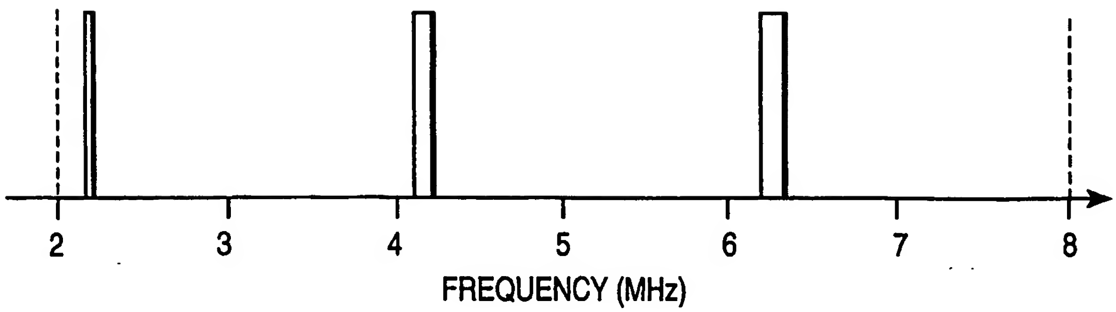


FIG. 5A

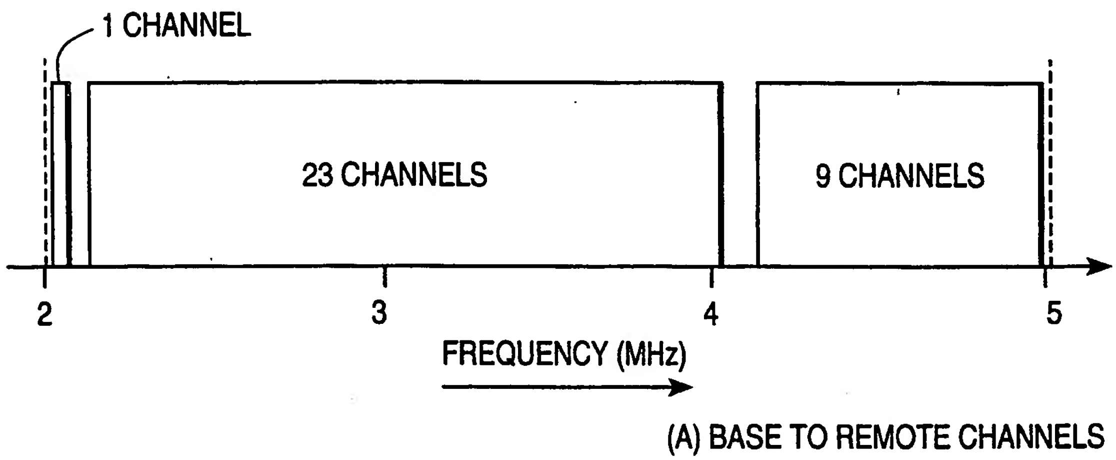


FIG. 5B

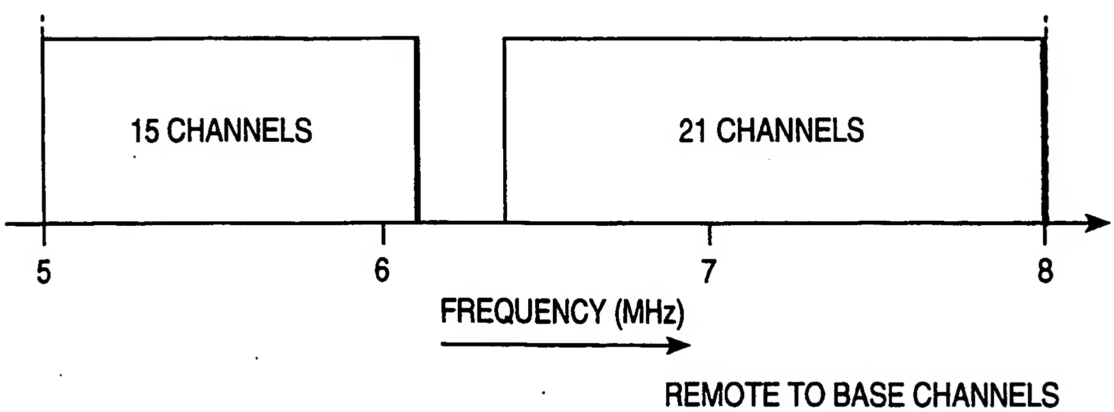


FIG. 5C

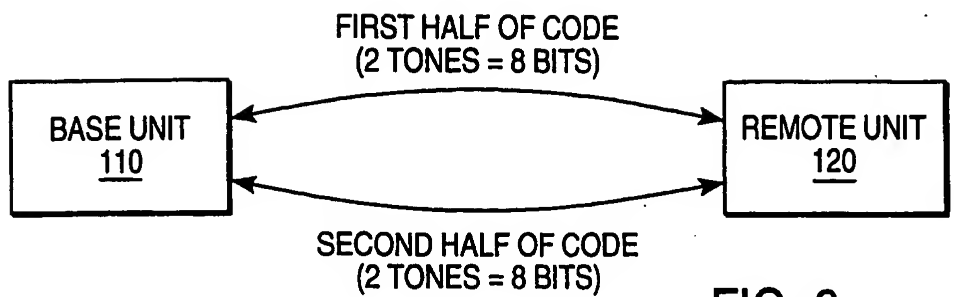


FIG. 6

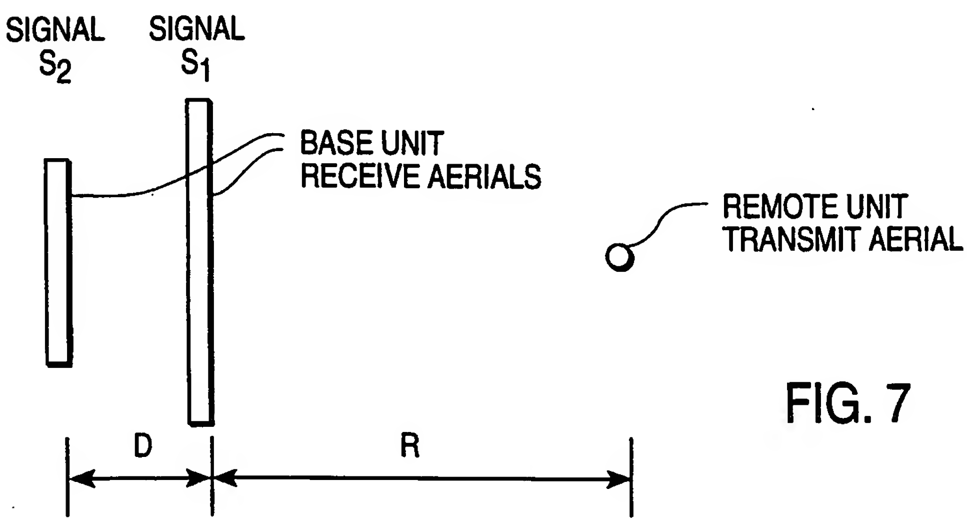


FIG. 7

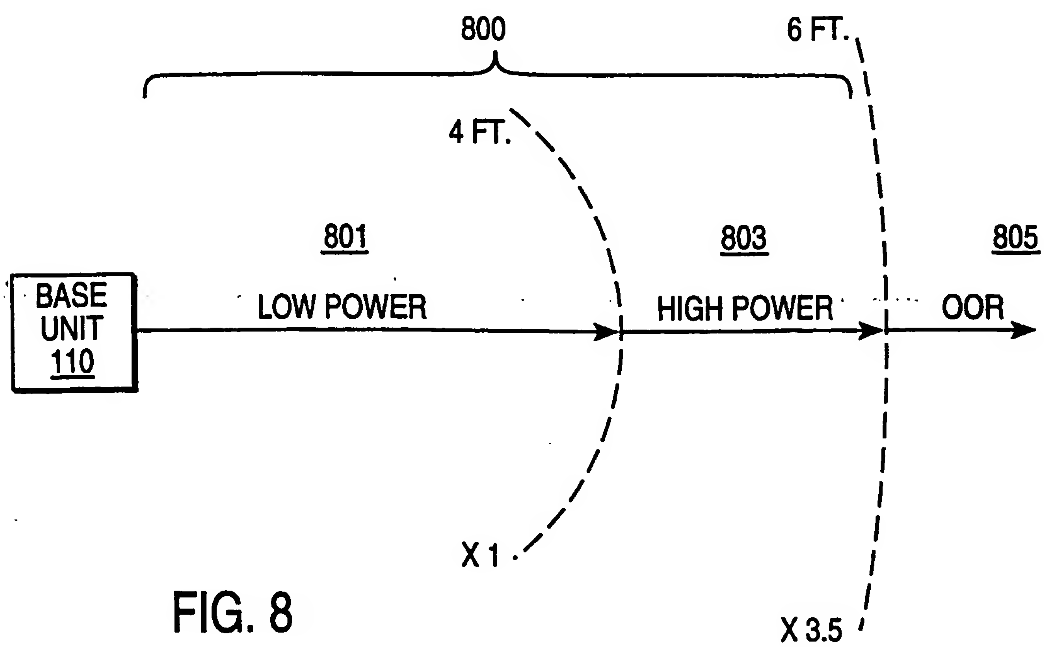


FIG. 8

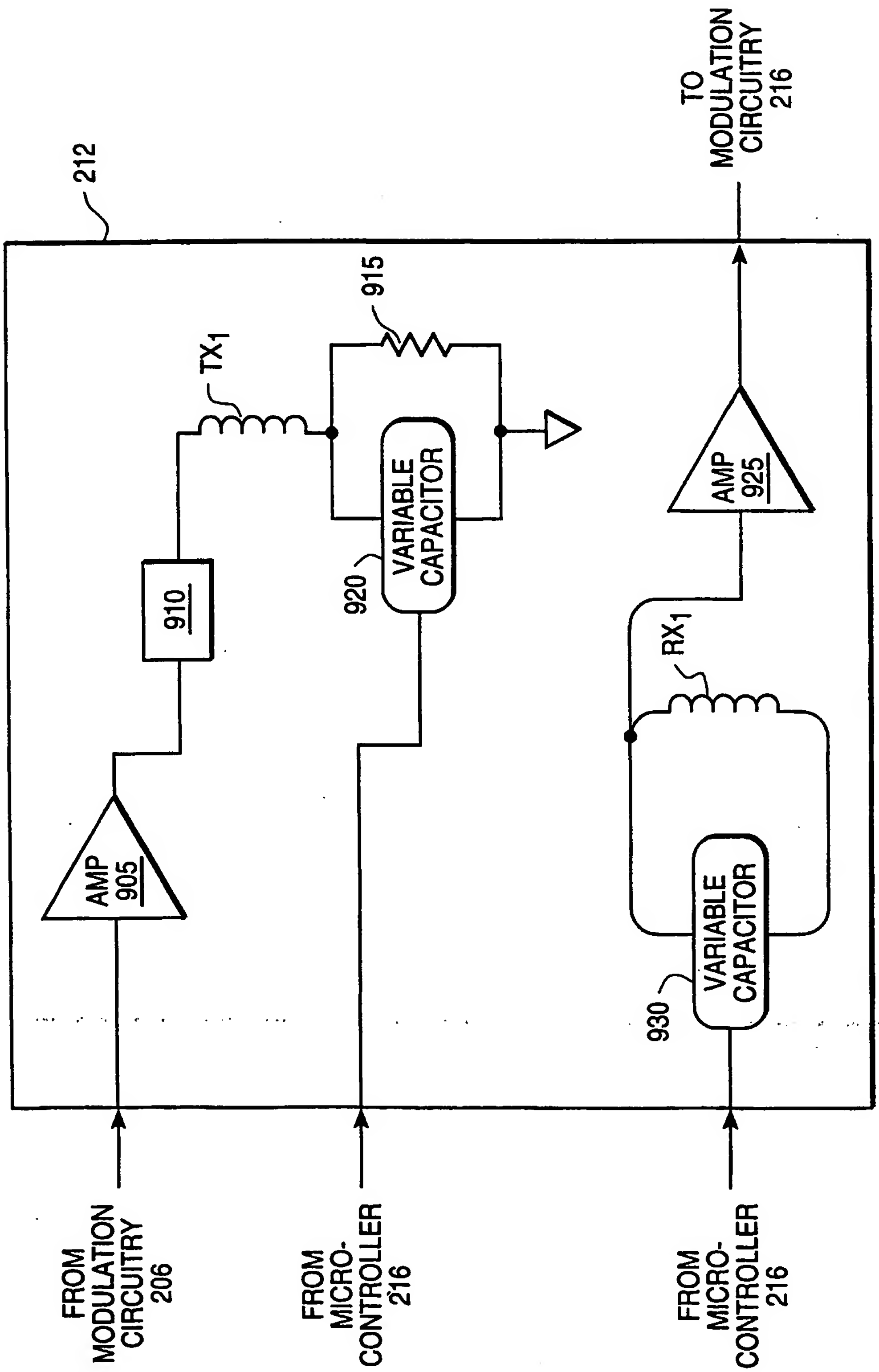

212
TO MODULATION CIRCUITRY 216
915
TX_1
910
VARIABLE CAPACITOR
920
AMP 905
AMP 925
RX_1
VARIABLE CAPACITOR
930
FROM MODULATION CIRCUITRY 206
FROM MICRO-CONTROLLER 216
FROM MICRO-CONTROLLER 216

FIG. 9

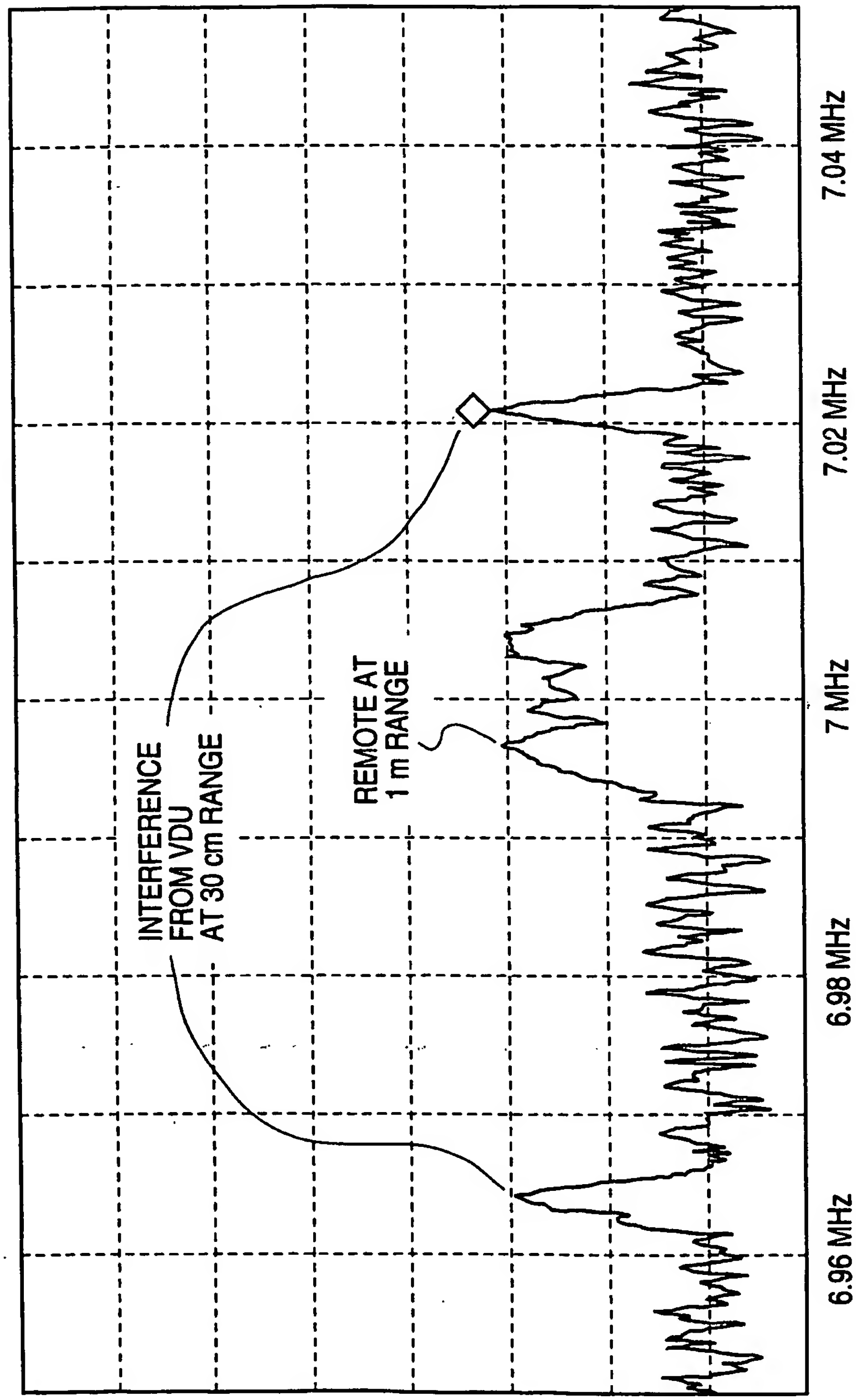

INTERFERENCE
FROM VDU
AT 30 cm RANGE
REMOTE AT
1 m RANGE
6.96 MHz
6.98 MHz
7 MHz
7.02 MHz
7.04 MHz

FIG. 10

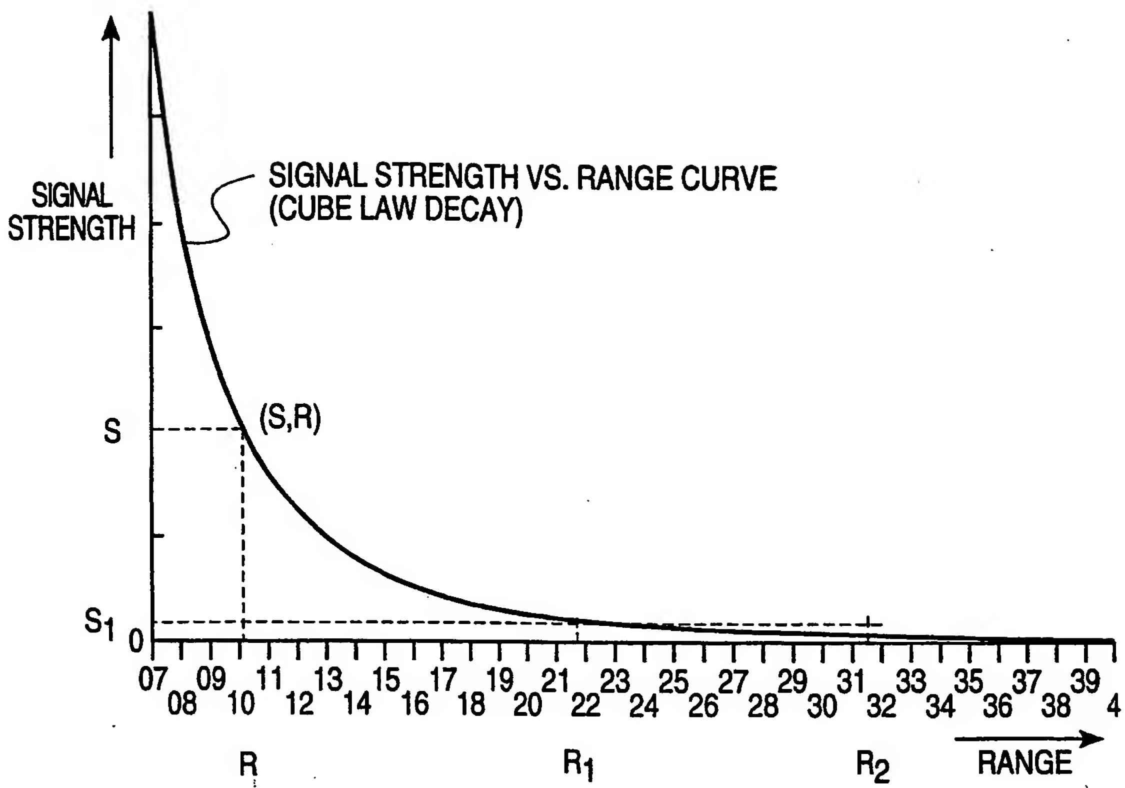


FIG. 11A

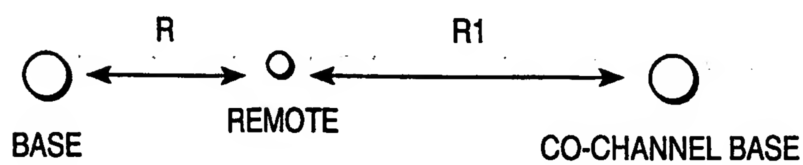


FIG. 11B

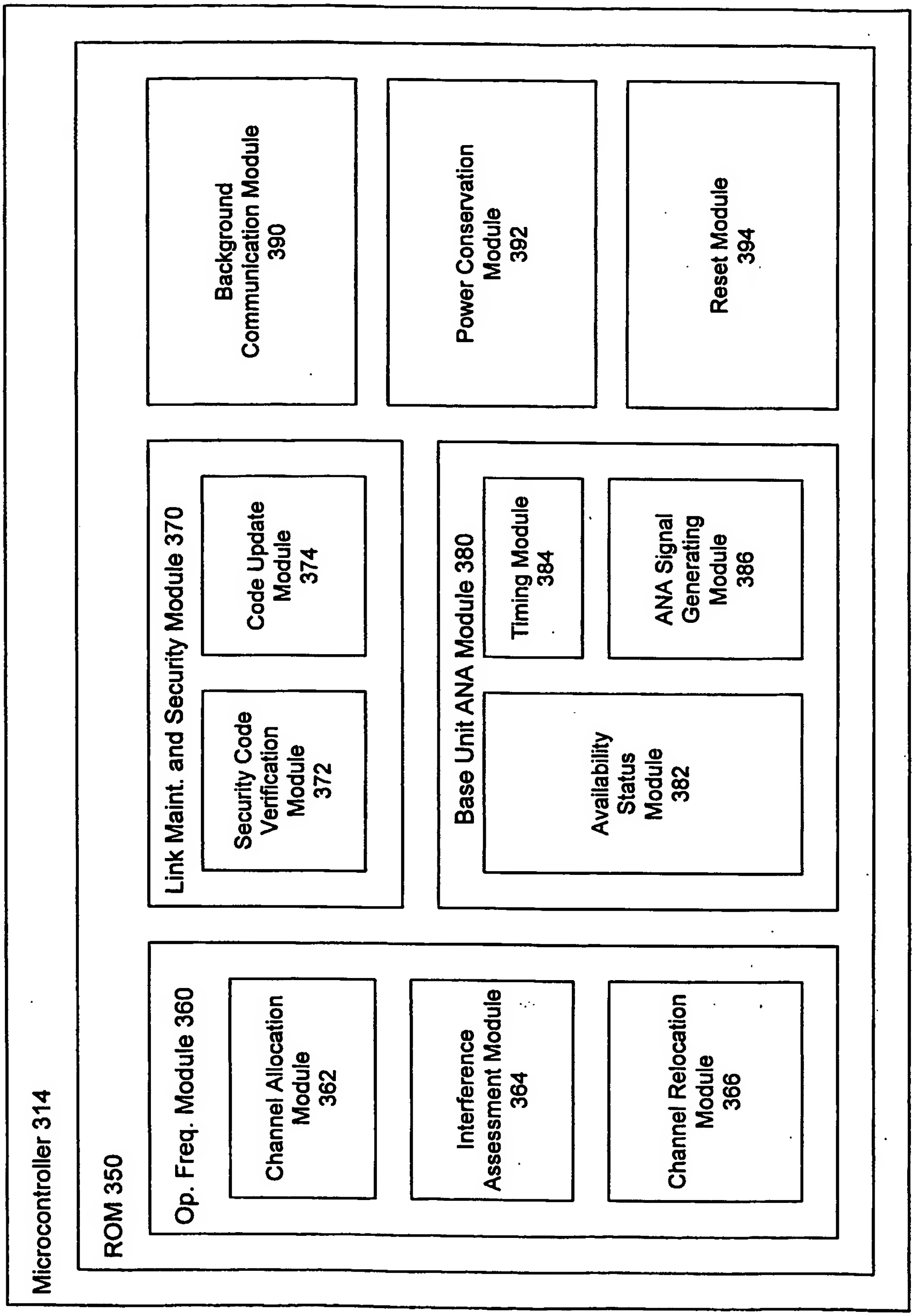

Microcontroller 314
ROM 350
Op. Freq. Module 360
Channel Allocation Module 362
Interference Assessment Module 364
Channel Relocation Module 366
Link Maint. and Security Module 370
Security Code Verification Module 372
Code Update Module 374
Base Unit ANA Module 380
Availability Status Module 382
Timing Module 384
ANA Signal Generating Module 386
Background Communication Module 390
Power Conservation Module 392
Reset Module 394

FIG. 12

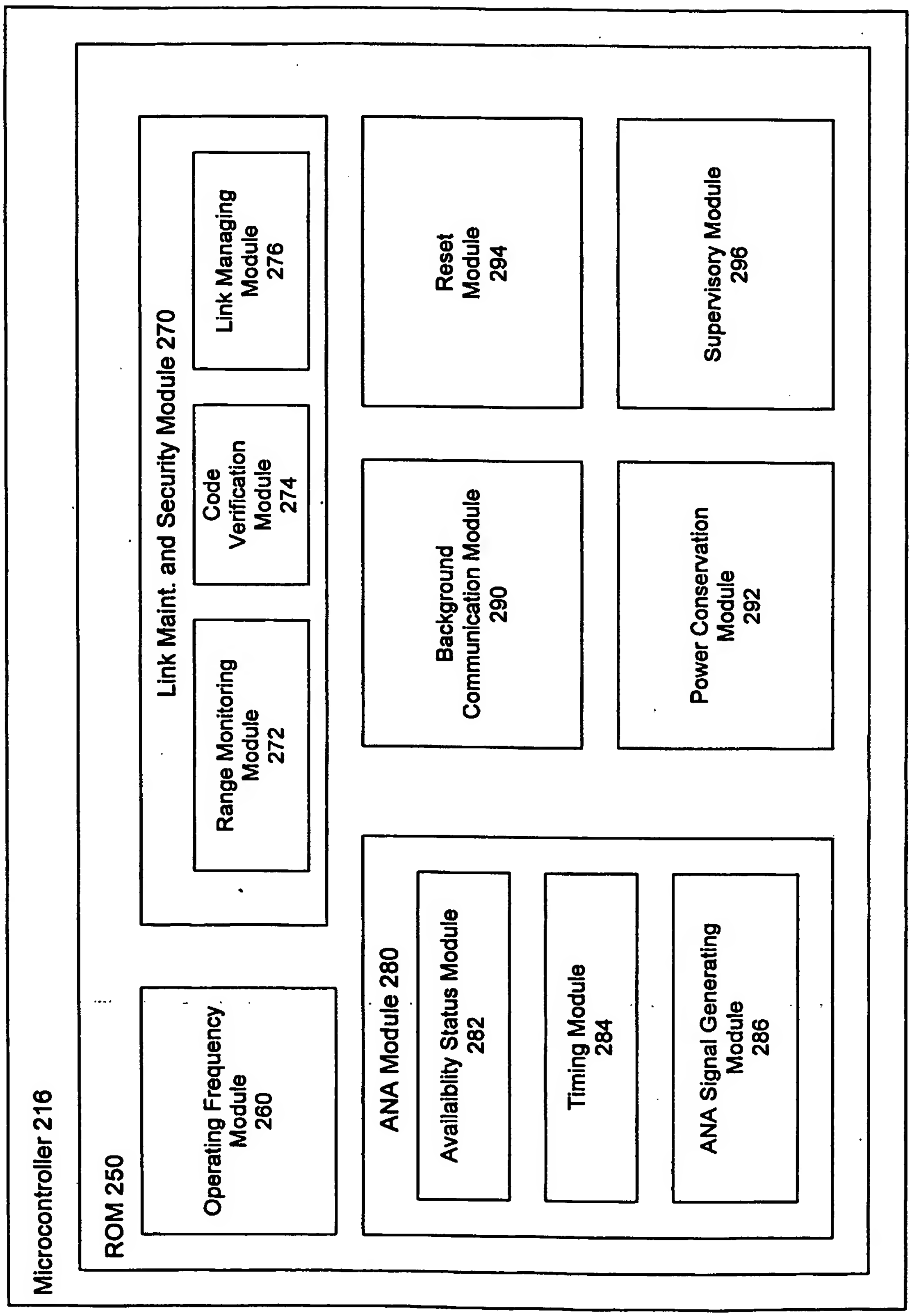

Microcontroller 216
ROM 250
Operating Frequency Module 260
Link Maint. and Security Module 270
Range Monitoring Module 272
Code Verification Module 274
Link Managing Module 276
ANA Module 280
Availaibility Status Module 282
Timing Module 284
ANA Signal Generating Module 286
Background Communication Module 290
Reset Module 294
Power Conservation Module 292
Supervisory Module 296

FIG. 13